TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

TABLE OF CONTENTS (Cont'd.)

Page

TABLES

FIGURES

TABLE OF CONTENTS (Cont'd.)

GROUND-WATER RESOURCES OF CHAMBERS AND JEFFERSON COUNTIES, TEXAS

ABSTRACT

The hydrologic units of Chambers and Jefferson Counties, the Chicot and Evangeline aquifers and the Burkeville aquiclude, are composed of gravel, sand, silt, and clay of Miocene, Pliocene, Pleistocene, and Holocene age.

Only small quantities of fresh ground water, less than 1,000 mg/l (milligrams per liter) dissolved solids, are available in Chambers and Jefferson Counties, and these supplies are fairly well developed. In 1965, approximately 18.6 mgd (million gallons per day) of ground water was used in the report area. Of this amount 10 mgd was fresh water produced from wells in adjacent Hardin and Orange Counties. Total pumpage of fresh water in Chambers and Jefferson Counties was approximately 6.1 mgd. About 2.5 mgd was slightly or moderately saline water.

Industrial use of ground water was approximately 9 mgd, of which 4 mgd was imported. Municipal use of ground water was approximately 8 mgd, of which 6 mgd was imported from Hardin County by the city of Beaumont. Irrigation use in 1965 was approximately 1.5 mgd. Use of ground water for irrigation will remain small because most of the available water is too saline.

Two aquifers, the Chicot (including the upper and lower units), and the Evangeline, furnish fresh water to wells. Fresh water is produced from wells in the Chicot aquifer in the Mont Belvieu, Houston Point, Anahuac, Galveston Bay, and Trinity Bay areas of Chambers County; in a small strip 2 to 4 miles wide along the eastern and northern boundaries of Jefferson County; and in the Hamshire-Winnie area of Chambers and Jefferson Counties. The Evangeline aquifer produces fresh water in the Mont Belvieu and Houston Point areas of Chambers County. Salinization of water in the aquifers has occurred in the vicinity of shallow salt domes.

Additional small supplies of fresh ground water can be developed in the present producing areas. The largest undeveloped source of fresh water underlies Galveston Bay in Chambers County. Large scale increased usage of ground water will require further importation from neighboring counties.

Most areas in both counties are underlain by very little or no fresh water, but large quantities of slightly and moderately saline ground water (1,000 - 10,000 mg/l) are present at shallow depths in all areas except in the vicinity of shallow salt domes.

Aquifer tests were made in 22 wells. Coefficients of permeability ranged from 108 to 1,670 gpd (gallons per day) per square foot. The highest permeability (1,670 gpd per square foot) was determined in a brackish-water well completed in the lower unit of the Chicot aquifer. The permeability of the sands of the Evangeline aquifer (244 and 327 gpd per square foot) approximate the permeability measured in the Houston district and in Jasper and Newton Counties.

Water levels have declined generally in both counties. The largest decline is due to pumping in adjacent Harris County. The maximum decline was estimated to be at least 150 feet in the lower unit of the Chicot aquifer in the area adjacent to Baytown in Harris County. This major decline has resulted in a land-surface subsidence of about 2 feet.

The exposed formations in Chambers and Jefferson Counties consist of Pleistocene and Holocene deposits, of which the Beaumont Clay of Pleistocene age is the oldest. Remnants of the relict Ingleside barrier island and beach system are enclosed within the Beaumont. The Deweyville deposits of Bernard (1950), which are topographically lower than the Beaumont, underlie the high terraces that border the Holocene floodplains of the Trinity and Neches Rivers. The Holocene deposits are alluvial and deltaic deposits and coastal marsh, mud flat, and beach (chenier) deposits, all comparatively low lying.

The Beaumont Clay, which is the most extensively exposed formation, is a sequence of deltaic and meander-belt deposits of the Pleistocene Trinity River. The Beaumont is probably less than 100 feet thick. On the basis of radiocarbon dating, the formation is probably more than 30,000 years old.

GROUND-WATER RESOURCES OF CHAMBERS AND JEFFERSON COUNTIES, TEXAS

INTRODUCTION

Purpose and Scope of the Investigation

The investigation of ground-water resources in Chambers and Jefferson Counties began in September 1965 as a cooperative project between the U.S. Geological Survey and the Texas Water Development Board. The purpose of the project was to determine the occurrence, availability, dependability, quality, and quantity of ground water suitable for public supply, industrial use, and irrigation.

The general scope of the investigation included the collection, compilation, and analysis of data; determination of the location and extent of the water-bearing formations; determination of the hydrologic characteristics of the water-bearing sands; a study of the chemical quality of the water; and estimates of the quantities of ground water available for development.

One section of the report presents a previously unpublished study of the Quaternary geology of the area.

Location and Extent of the Area

Chambers and Jefferson Counties are situated on the upper Texas Gulf Coast in the West Gulf Coastal Plain physiographic province (Fenneman, 1938). The two counties, which have a combined area of 1,562 square miles, are bounded on the north by Liberty and Hardin Counties; on the east by the Neches River, Sabine Lake, and Orange County; on the south by Galveston Bay and the Gulf of Mexico; and on the west by Galveston Bay, Cedar Bayou, and Harris County. Anahuac, the county seat of Chambers County, is 40 miles east of Houston; Beaumont, the county seat of Jefferson County, is 80 miles east of Houston (Figure 1).

Figure 1.—Location of Chambers and Jefferson Counties

Economic Development

The largest segment of the economy of Chambers and Jefferson Counties is based on the production of petroleum, petrochemicals, natural gas, and sulfur. Since the discovery of oil at Spindletop in 1901, a total of approximately 800 million barrels have been produced in the two counties.

Beaumont and Port Arthur are centers of a petroleum-based industrial complex served by the Intracoastal Waterway and other canals suitable for ocean-going vessels. Timber, cattle, fresh and salt-water fish, and agricultural products are other important elements of the economy.

In 1965, Chambers and Jefferson Counties had estimated populations of 11,100 and 268,000, respectively. Anahuac, the largest town in Chambers County, had a 1965 population of 2,200; Beaumont, the largest city in Jefferson County, had a 1965 population of 127,800.

Climate

Chambers and Jefferson Counties have a warm humid climate. Precipitation, which averages about 54 inches annually, is well distributed throughout the year but is greatest from May to September.

The average annual temperature at Beaumont is about 21°C (70°F). Temperatures below freezing occur on the average of only 12 days per year, and temperatures about 38°C (100°F) are unusual. The approximate dates of the first and last killing frosts are December 2 and March 2. The average annual precipitation, average monthly temperature, and average monthly precipitation at Beaumont for the period of record beginning in 1931 are shown in Figure 2.

Gross lake-surface evaporation averaged about 47 inches annually for the period 1940 to 1965 (Kane, 1967).

Physiography and Drainage

Chambers and Jefferson Counties are on the extreme seaward margin of the West Gulf Coastal Plain physiographic province and entirely within the Grassland Coastal Prairie Region of Texas (Walker and Miears, 1957). The physiography is of three general types: (1) flat to gently rolling upland, which includes most of the area; (2) the valleys of the Trinity and Neches Rivers; and (3) the coastal border. Altitudes range from sea level to a maximum of 81 feet above sea level at Mont Belvieu (Barbers Hill salt dome) in western Chambers County.

Along a line from Smith Point to Beaumont, a series of remnants of abandoned beaches and beach ridges reach altitudes ranging from 15 to 25 feet. The more prominent of these sandy remnants are about 5 feet above the upland surface. Salt domes form two prominent hills on the upland surface: Barbers Hill, in northwestern Chambers County, about 40 feet above the general land surface and Big Hill, in southwestern Jefferson County, about 20 feet high.

The major streams in Chambers County are the Trinity River, which drains the northwestern part of the county and flows into Trinity Bay near Anahuac; Cedar Bayou, which forms the western boundary of the county and flows into Galveston Bay; Double Bayou, which drains the central part of the county and flows into Trinity Bay south of Anahuac; and Oyster Bayou, Onion Bayou, and East Bay Bayou, which drain the eastern part of the county and flow into East Bay.

The major streams in Jefferson County are the Neches River, which drains the eastern part of the county and flows into Sabine Lake; Pine Island Bayou, which forms the northern boundary of the county and flows into the Neches River; Taylor Bayou and its principal tributaries, Hillebrandt and Big Hill Bayous, which drain the western part of the county and flow into Sabine Lake south of Port Arthur; and Spindletop and Salt Bayous, which drain the southern part of the county and flow into the Intracoastal Waterway.

Urbanization and rice cultivation have resulted in the canalization of many streams and the construction of ditches and canals for drainage and irrigation. In some places, natural drainage directions have been changed by deepening parts of the streams.

Methods of Investigation

The following items were included in the investigation of the ground-water resources of Chambers and Jefferson Counties:

1. An inventory was made of all industrial, public supply, and irrigation wells, and of a representative number of domestic and livestock wells (Table 4). Locations of the wells are shown on Figure 24.

2. Electrical logs and drillers' logs of water wells and oil tests were used for construction of the hydrologic sections (Figures 25 through 28) and for determination of the total thickness of sands containing fresh water (Figures 17 and 18).

3. An inventory was made of the withdrawal of ground water for public supply, irrigation, and industrial use.

4. Pumping tests were made to determine the hydraulic characteristics of the water-bearing sands (Table 2).

5. Altitudes of water wells were determined from topographic maps.

6. Measurements of water levels were made in wells, and available records of past fluctuations of water levels were compiled (Table 6 and Figures 8 through 11).

7. Climatological records were collected and compiled (Figure 2).

8. Analyses of water samples were made to determine the chemical quality of the water (Table 7).

9. Maps, sections, and graphs were prepared to correlate and illustrate geologic and hydrologic data.

10. The hydrologic data were analyzed to determine the quantity and quality of ground water available for development.

11. Data were compiled on the subsidence of the land surface (Figure 12).

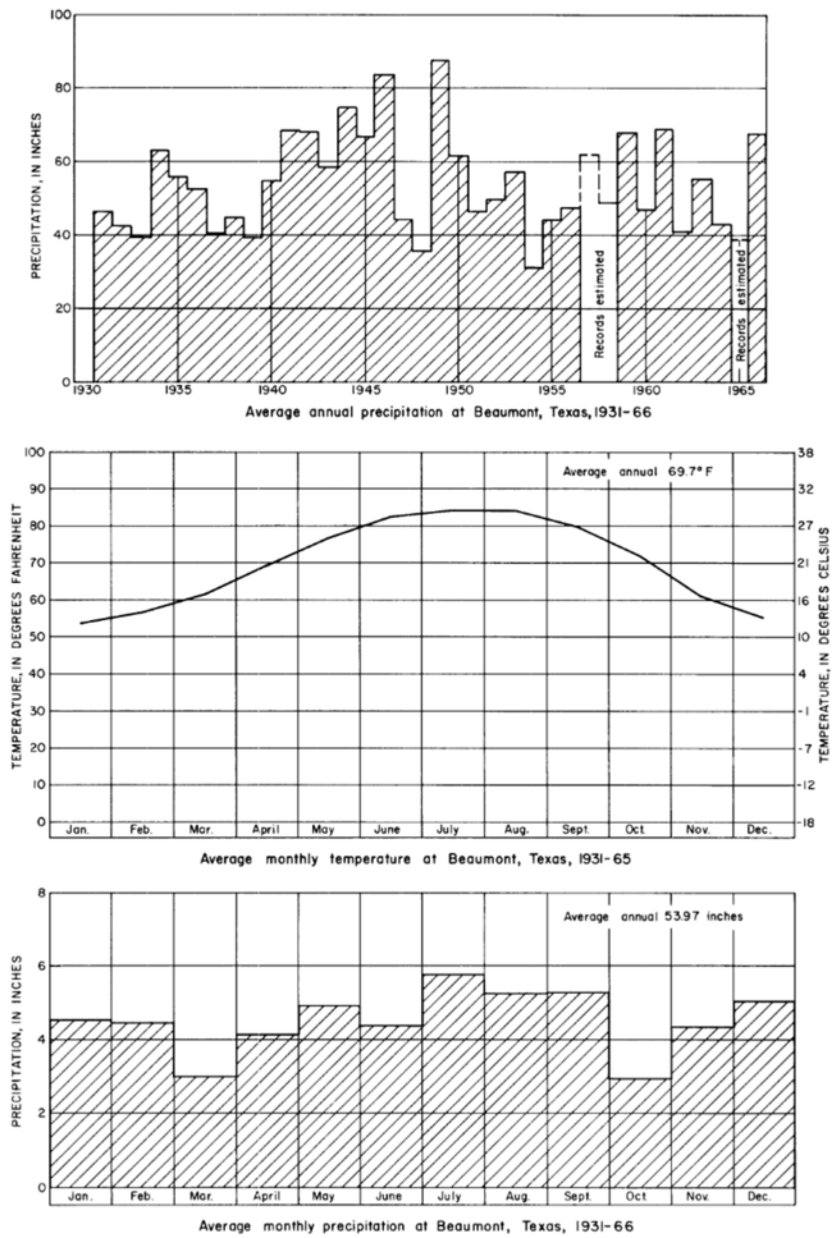

Figure 2

Average Annual Precipitation, Average Monthly Temperature, and Average Monthly Precipitation at Beaumont

From records of U.S. Weather Bureau

12. Problems related to the development and protection of ground-water supplies were studied.

Previous Investigations

Taylor (1907) included wells in Chambers and Jefferson Counties in his report on the underground waters of the Coastal Plain of Texas. Duessen (1914), in a reconnaissance report on the underground waters of the southeastern part of the Texas Coastal Plain, discussed the ground-water geology of Chambers and Jefferson Counties and included a list of wells and springs and drillers' logs of wells.

Livingston and Cromack (1942) inventoried wells in Chambers and Jefferson Counties in 1941 and 1942, and Doyel (1956) published an updated report on Chambers County. Much of the data in these reports was used in this investigation.

Reports by Wood (1956), and Wood, Gabrysch, and Marvin (1963) discussed the ground-water supplies available from the principal water-bearing formations in the Gulf Coast region of Texas, including Chambers and Jefferson Counties.

Water levels have been measured and water samples collected systematically since 1949 in the western part of Chambers County as part of a continuing ground-water program in Harris and Galveston Counties.

Periodic measurements of water levels in wells in Chambers and Jefferson Counties have been made since 1949 as part of the statewide observation-well program in Texas. Records of these measurements are published periodically by the Texas Water Development Board, and records of selected wells in Chambers and Jefferson Counties are published by the U.S. Geological Survey in reports on water levels and artesian pressures in the United States (Hackett, 1962).

Well-Numbering System

The well-numbering system used in this report is the system adopted by the Texas Water Development Board for use throughout the State. Under this system, each 1-degree quadrangle in the State is given a number consisting of two digits. These are the first two digits in the well number. The 1-degree quadrangles are divided into 7½-minute quadrangles which are given two-digit numbers from 01 to 64. These are the third and fourth digits of the well number. Each 7½-minute quadrangle is subdivided into 2½-minute quadrangles and given a single digit number from 1 to 9. This is the fifth digit of the well number. Each well within a 2½-minute quadrangle is given a two-digit number as it is inventoried, starting with 01. These are the last two digits of the well number.

Only the last three digits are shown on the well-location map (Figure 24). The second two digits are generally shown in the northwest corner of each 7½-minute quadrangle, and the first two digits are shown by the large double-lined numbers.

In addition to the 7-digit well number, a two-letter prefix is used to identify the county. Prefixes for Chambers, Jefferson, and adjacent counties are as follows:

COUNTY	PREFIX	COUNTY	PREFIX
Chambers	DH	Hardin	LH
Jefferson	PT	Liberty	SB
Orange	UJ	Harris	LJ

Thus, well DH-64-11-802 (which supplies water for the city of Anahuac) is in Chambers County (DH), in the 1-degree quadrangle 64, in the 7½-minute quadrangle 11, in the 2½-minute quadrangle 8, and was the 2nd well (02) inventoried in that 2½-minute quadrangle.

Acknowledgments

The author acknowledges the assistance of the many county, municipal, and industrial officials who aided in this project. Particular appreciation is expressed to Jett Hankamer and to personnel of Humble Oil and Refining Co., Mobil Oil Corp., Pure Oil Co., Placid Oil Co., Gulf States Utilities Co., Diamond Alkali Co., Warren Petroleum Corp., and Chambers County Water Control and Improvement District No. 1 for permitting and assisting in pumping tests in wells. The Houston Lighting and Power Co. furnished information as it was collected in their testing program east of Baytown.

Well drillers supplied drillers' logs, electrical logs, and well-completion data; and all landowners contacted granted access to their property, wells, and records.

Dr. Saul Aronow, Department of Geology, Lamar State College of Technology, prepared the section of the report on Quaternary geology and aided the author in the task of relating geology to hydrology.

HYDROLOGIC AND GEOLOGIC UNITS

The geologic units composing the aquifers in Chambers and Jefferson Counties are, from oldest to youngest: the Fleming Formation of Miocene age; the Goliad Sand of Pliocene age; the Willis Sand of Pliocene(?) age; the Bentley Formation, Montgomery Formation, and Beaumont Clay of Pleistocene age; the Deweyville deposits of Bernard (1950) of Pleistocene(?) age; and the alluvial, deltaic, coastal marsh, mudflat, and beach (chenier) deposits of Holocene age. The correlation of geologic and hydrologic units is shown in Table 1.

The Beaumont Clay and the Holocene deposits (described in the section on Quaternary geology) crop out within the two counties. Their surface relationships are shown on the geologic map (Figure 20). The older formations crop out in the counties to the north.

The geologic units are generally composed of sand, silt, and clay, with lesser amounts of gravel, marl, and lignite. Faults are common, especially in the vicinity of salt domes, but surface traces of the fault zones are rarely discernible. Some, but not all, of the salt domes are marked by surface features such as higher altitudes, topographic depressions, or a combination of both.

Figures 25, 26, 27 and 28 are hydrologic sections showing the aquifers, their stratigraphic relationship, and the salinity of the water they contain.

Burkeville Aquiclude

The Burkeville aquiclude, the lowermost hydrologic unit discussed in this report, is principally a clay section within the Fleming Formation and is equivalent, at least in part, to the Castor Creek Member (Fisk, 1940) of the Fleming Formation of Kennedy (1892), as mapped by Rogers and Calandro (1965) in Vernon Parish, Louisiana. The Burkeville is also equivalent to "Zone 2" of Lang, Winslow, and White (1950) in the Houston district.

The Burkeville ranges in thickness from 130 to 300 feet. The unit contains minor amounts of sand in some places but is not a source of water in Chambers and Jefferson Counties. The significance of the Burkeville in the two counties is that it forms the lower confining layer for the overlying Evangeline aquifer.

Evangeline Aquifer

The Evangleine aquifer is the lowermost unit containing fresh or slightly saline water in Chambers and Jefferson Counties. The Evangeline overlies the Burkeville aquiclude and includes the Goliad Sand and sands in the upper part of the Fleming Formation. The aquifer is equivalent to the "heavily pumped" layer of Wood and Gabrysch (1965) in the Houston district. In Louisiana, the unit is equivalent to the Blounts Creek Member (Fisk, 1940) of the Fleming Formation of Kennedy (1892) in Vernon Parish (Rogers and Calandro, 1965) and the Foley Formation in Calcasieu Parish (Harder, 1960).

The Evangeline is about 1,400 feet thick in northern Jefferson County and increases in thickness toward the Gulf. The aquifer yields fresh water to large wells in northwestern Chambers County.

Chicot Aquifer

The Chicot aquifer includes all deposits above the Evangeline aquifer. The unit consists of the Willis Sand, the Bentley Formation, the Montgomery Formation, the Beaumont Clay, the Deweyville Deposits of Bernard (1950), and the Holocene alluvium.

The physical basis for separation of the Evangeline and Chicot is the difference in lithology and permeability. In some areas, the two aquifers are separated by beds of clay, but such beds are not continuous. The units differ in average grain size, cementation, and compaction. The higher permeabilities are usually associated with the Chicot.

The differences noted may be recognized in ways other than by examination of the sediments. A displacement of the spontaneous-potential curve of an electrical log as the logging tool passes out of the Evangeline into the Chicot often marks the contact between the two lithologically dissimilar aquifers. In addition, the formation factor (ratio between aquifer resistivity and aquifer water resistivity) for the two aquifers is generally significantly different. The formation factor for the Chicot aquifer is usually greater. In some areas, where lithologic differences are not pronounced or where changes in water quality makes comparative readings difficult or impossible, the contact between the two aquifers is not readily apparent from electrical logs.

In parts of eastern Jefferson County and western Chambers County, the Chicot aquifer is divided into two units by a clay bed that separates an upper sand section from a lower sand section. There are significant differences in water levels in wells completed in the upper and lower units of the Chicot in eastern Jefferson County and western Chambers County. These sands merge in some places, and in other places, one of the sands may be absent.

In some parts of the two counties, the upper and lower units of the Chicot merge into one large mass of interbedded and interconnected sand and clay as much as 1,600 feet thick. In these areas, determination of a boundary between the two units becomes impossible. This is especially true near some of the shallow piercement-type salt domes and in a large area in central Chambers County. The configuration of the base of the Chicot aquifer and the locations of most of the salt domes in the area are shown on Figure 3.

Lower Unit

In the downdip (southeast) parts of Chambers and Jefferson Counties, the lower unit of the Chicot aquifer is generally two or more massive sands separated by clay. These sands are probably equivalent to the "500-foot" and "700-foot" sands as mapped in Calcasieu Parish, Louisiana (Harder, 1960). In reports on Galveston and Harris Counties, the massive sands of the lower Chicot

Table 1.--Geologic and Hydrologic Units Used in This Report and in Recent Reports in Nearby Areas

		HARDER (1960)		ROGERS AND CALANDRO (1965)		RECENT TEXAS REPORTS		BAKER (1964)	WESSELMAN (1965)	WOOD AND GABRYSCH (1965)	1/	THIS REPORT	
SYSTEM	SERIES	FORMATION	HYDROLOGIC UNIT	GROUP OR FORMATION	HYDROLOGIC UNIT	FORMATION		HYDROLOGIC UNIT	HYDROLOGIC UNIT	HYDROLOGIC UNIT	HYDROLOGIC UNIT	HYDROLOGIC UNIT	
Quaternary	Holocene	Alluvium		Alluvium	Alluvium	Alluvium 2/		GULF COAST AQUIFER		Beaumont		Upper Chicot	Chicot aquifer
	Pleistocene	Prairie Formation	Chicot shallow	Stream terrace and upland deposits	Stream terrace and upland deposits	Beaumont Clay			Upper aquifer		Chicot aquifer		
		Montgomery Formation	"200 foot"			Lissie Formation 3/	Montgomery Formation		Middle aquifer	Alta Loma Sand of Rose (1943)			
		Bentley Formation	"500 foot"				Bentley Formation					Lower Chicot	
		Willianna Formation	"700 foot"			Willis Sand 4/							
Tertiary	Pliocene	Foley Formation	Evangeline aquifer	Fleming Formation ? of Kennedy (1892)	Blounts Creek Member ? of Fisk (1940)	Goliad Sand			Lower aquifer	Heavily pumped layer	Evangeline aquifer	Evangeline aquifer	
	?	Fleming Formation of Fisk (1940)	?		Castor Creek Member of Fisk (1940)	Fleming Formation 5/							
	Miocene									Zone 2	Burkeville aquiclude	Burkeville aquiclude	

1/ Wesselman (1967), Tarver (1968a and 1968b), Anders and others (1968), Sandeen (1968), and Wilson (1967).
2/ Floodplain and terrace deposits in Baker (1964).
3/ Lissie Formation in Baker (1964), Wesselman (1965 and 1967), Sandeen (1968), and Anders and others (1968); and Bentley and Montgomery Formations in Wilson (1967) and Tarver (1968a and 1968b).
4/ Pliocene (?).
5/ Shown as the Lagarto Clay of Miocene (?) age in Baker (1964) and Wesselman (1967).

unit have been mapped as the Alta Loma Sand of Rose (1943). In Orange County (Wesselman, 1965), the sands were mapped together as the "middle" aquifer.

In much of the updip (northwest) parts of Chambers and Jefferson Counties, the lower unit of the Chicot thins and loses much of the sand that is present downdip. Much of this loss is due to wedging of the unit, but some of the loss is due to facies changes.

Upper Unit

The upper unit of the Chicot consists of a basal sand overlain by clay. Most of the sand is part of the Montgomery Formation and can be traced into the outcrop of this geologic unit. The uppermost overlying clay is Beaumont, but in many places clay of the Montgomery Formation is also present.

No criteria other than the mapping of terrace levels have been developed for separating the Beaumont sands or sands of Holocene age from the underlying sands of the Montgomery Formation. The basal sand of the upper unit of the Chicot may be correlated with the "200-foot" sand of Calcasieu Parish, Louisiana (Harder, 1960).

SOURCE AND OCCURRENCE OF GROUND WATER

The principal source of fresh ground water in Chambers and Jefferson Counties is precipitation. Most precipitation runs off and becomes streamflow or evaporates immediately. Only a small fraction of the rainfall infiltrates to the zone of saturation. The zone of saturation is the zone below the water table where the interstices in the rocks are filled with water. Much of the penetrating water is rapidly returned to the atmosphere by evaporation or transpiration. A large percentage of the water that reaches the zone of saturation in the aquifers is rapidly returned to the surface as spring flow, which supports the base flow of the streams of the area.

Ground water occurs in aquifers. An aquifer is a geologic formation, group of formations, or part of a formation that is water bearing. An aquiclude is an impermeable or relatively impermeable bed that may contain water but is incapable of transmitting an appreciable quantity.

The water in an aquifer exists under one of two conditions, water table or artesian. Under water-table conditions, the water contained in the aquifer is under atmospheric pressure only. The water table is free to rise or fall in response to changes in the volume of water stored. A well penetrating an aquifer under water-table conditions fills with water to the level of the water table.

Artesian conditions occur when an aquifer is overlain by sediments of lower permeability that confine the water under hydrostatic pressure. Such conditions occur downdip from the outcrops of the aquifers. A well penetrating sands under artesian head (pressure) becomes filled with water to a level above the top of the aquifer. If the head (pressure) is great enough to raise the water to a level higher than the top of the well, the water flows. The height above the aquifer that the water will rise in a well is equivalent to the pressure head in the aquifer.

The water in the aquifers moves under the influence of gravity from areas of recharge to areas of discharge. The average velocity of movement is slow, less than a foot a day, except in the immediate vicinity of large wells or springs.

Discharge of ground water occurs both naturally and artificially. Natural means of discharge include evapotranspiration, spring flow, and upward seepage through clays. Artificial discharge is accomplished by pumping from wells; by pumping from excavations that intersect the water table; or by drainage that results when ditches are cut into and below the water table.

RECHARGE, MOVEMENT, AND DISCHARGE OF GROUND WATER

Before man began developing ground water in the Gulf Coast regions, the deeper aquifers had a higher head than the more shallow ones. The original higher piezometric head on the deeper aquifer systems was caused by the outcrops of the deeper aquifers being topographically higher. Downdip from the outcrops, movement of water was generally southeastward, in the direction of the hydraulic gradients, toward areas of natural discharge.

In much of the area, continuous clay beds confined the water, and the only avenue of discharge was upward through the clays. However, in some areas of low altitude, the aquifer sands are not overlain by clay, and fresh water was discharged through the sands. One such area is located between Smiths Point and Monroe City, 6 miles east of Anahuac, in Chambers County and another in the Pine Island Bayou and Neches River lowlands north and east of Beaumont. Much of the artesian fresh water that entered from surrounding counties was discharged as spring flow or seepage in these and similar areas.

The interconnection of the aquifers along the sides of the shallow piercement-type salt domes also provide avenues of discharge. Interconnection is indicated by electric logs and by water-quality data in the vicinity of Barbers Hill, Lost Lake, Moss Bluff, Fannett, Big Hill, and Spindletop Domes (Figure 3).

Originally, fresh and saline waters moved toward these domes under sufficient artesian heads to cause water to flow above land surface. Much of this water was, or became, salty as it passed adjacent to the domes from the lower aquifers to the upper aquifers. Interconnection of the aquifers allowed this deeper and usually more saline water with its higher piezometric head to rise and mix with the fresher water in the upper aquifers. A generalized illustration showing ground-water movement near domes was published by Hanna (1958, p. 11). It is reproduced here as Figure 4.

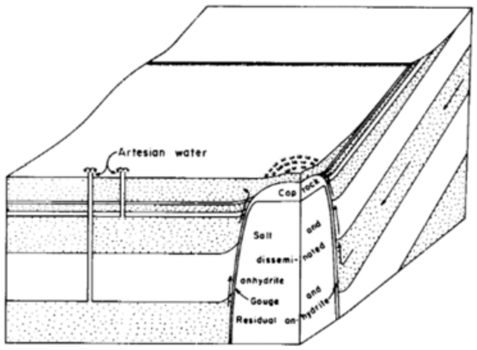

Figure 4.—Idealized Block Diagram Illustrating Ground-Water Circulation Around Salt Domes

Since the development of the ground-water resources of this region began in the 1800's, the subsurface circulation of the water has been changed repeatedly, and new recharge-discharge relationships have been established. Because of ground-water development, water levels declined. Cones of depression around each well altered the natural flow pattern, and water now moves from all directions into these centers of pumping. Withdrawals from the aquifers in Harris and Orange Counties have established large regional cones of depression that extend into Chambers and Jefferson Counties. A smaller cone of depression has been established by pumping in the Winnie-Hamshire area.

The cones of depression have lowered the piezometric surface below land surface in the artesian aquifers at all observed points, and below sea level in much of the area. Because of this alteration, the previously described areas of discharge have, or will soon become, areas of recharge to the underlying aquifers.

Specifically, some parts of the upper unit of the Chicot aquifer in Chambers and Jefferson Counties which formerly discharged water as springs and seeps are probably now recharged with fresh water through these outcrops of sand within the counties. Probably most of the lower unit of the Chicot and the Evangeline aquifers are still recharged through outcrops in adjoining or nearby counties.

HYDRAULIC CHARACTERISTICS OF THE AQUIFERS

"The worth of an aquifer as a fully developed source of water depends largely on two inherent characteristics: its ability to store and its ability to transmit water" (Ferris and others, 1962, p. 70). These characteristics are measured by the coefficients of storage and transmissibility.

The coefficient of storage is important in any calculation of the quantity of water that can be obtained from an aquifer; but the availability of the water, especially in an artesian aquifer, depends primarily on the ability of the aquifer to transmit water. The coefficient of permeability is a measure of that ability and is defined as the rate of flow of water in gallons per day through a cross-sectional area of 1 square foot under a unit-hydraulic gradient (1 foot per foot) at a temperature of 16°C (60°F). In field practice the adjustment to the standard temperature of 16°C (60°F) is commonly disregarded, and the permeability is then understood to be a field coefficient at the prevailing water temperature. The coefficient of transmissibility is the product of the field coefficient of permeability and the saturated thickness of the aquifer.

The specific capacity of a well is its yield per unit drawdown and can be theoretically related to transmissibility. It is expressed in gallons per minute per foot of drawdown. The measured specific capacity may differ from the computed theoretical specific capacity of a well for one or more reasons. Improper well construction and development, screen losses, unfavorable local geologic conditions, screening only part of the available aquifer—all are factors that will decrease the measured specific capacity. On the other hand, in some wells the effective diameter of the well may be increased by proper development. As a result, the measured specific capacity can be larger than the theoretical. Wood and others (1963, p. 40), referring to the Gulf Coast region, reported that ". . . the measured specific capacities of most wells in the region are smaller than the theoretical, indicating that many of the sands in the gravel-packed zone are poorly connected to the interior of the screen so that screen losses are considerable during pumping."

The coefficients of storage and transmissibility of the aquifers were determined by aquifer tests made in wells in Chambers and Jefferson Counties. The test data were analyzed by the Theis non-equilibrium method as modified by Cooper and Jacob (1946, p. 526-534), or by the Theis recovery method (Wenzel, 1942, p. 95-97). The results of the tests and specific capacities of the wells are shown in Table 2. None of the wells are completed in a full section of an aquifer, therefore the values in the table are less than the aquifer's total capability.

The coefficients of transmissibility and storage may be used to predict drawdowns in water levels caused by pumping. The theoretical relation between drawdown and distance from the center of pumping for different coefficients of transmissibility is shown on Figure 5. The calculations of drawdown are based on a withdrawal of 1 mgd (million gallons per day) for 1 year from an aquifer having coefficients of transmissibility and storage as shown and assuming the aquifer has infinite areal extent. For example, if the coefficients of transmissibility and storage are 50,000 gpd (gallons per day) per foot and 0.001, respectively, the drawdown or decline in the water level would be 12 feet at a distance of 1 mile from a well or group of wells discharging 1 mgd for 1 year. If the coefficients of transmissibility and storage are 5,000 gpd per foot and 0.0001, respectively, the same pumping rate for the same time would cause 84 feet of decline at the same distance.

Figure 6 shows the relation of drawdown to distance and time as a result of pumping from an artesian aquifer with characteristics similar to those found in the artesian aquifers of Chambers and Jefferson Counties. To prepare these curves, it was assumed that the aquifers had infinite areal extent. This illustration shows that the rate of drawdown decreases with time. For example, the drawdown at 100 feet from a well is 11 feet after 1 mgd has been pumped for 1 year, and the drawdown is about 15 feet after 1 mgd has been pumped for 100 years. The total drawdown at any one place within the cone of depression (or influence) of several wells would be the sum of the influences of the several wells. The equilibrium curve illustrates the time-drawdown relation when a line source of recharge is 25 miles from the point of discharge.

Figure 7 shows the relation of drawdown to distance and time as a result of pumping from a water-table aquifer with characteristics similar to small parts of the upper unit of the Chicot aquifer. Again, infinite areal extent of the aquifer is assumed. The drawdown is less than that in an artesian aquifer because, under water-table conditions, the coefficient of storage is larger.

Interference between wells may cause a decrease in yield of the wells, or an increase in pumping costs, or both. If the pumping level declines below the top of the aquifer screened, the saturated thickness of the aquifer decreases and the result is a decrease in the yield of the well.

Aquifer tests were run on 10 wells tapping the lower unit of the Chicot aquifer in Chambers and Jefferson Counties. Coefficients of transmissibility ranged from 5,200 to 401,000 gpd per foot and coefficients of permeability ranged from 108 to 1,670 gpd per square foot. The highest permeability was determined from a test of a saline-water well completed in the lowermost massive sand in the lower unit of the Chicot. Specific capacities ranged from 3.4 to 32.5 gpm (gallons per minute) per foot. The coefficient of storage in the lower unit of the Chicot ranged from 0.0004 to 0.0037.

Tests of 9 wells completed in the upper unit of the Chicot showed the following ranges in coefficients: transmissibilities from 10,800 to 29,800 gpd per foot; permeabilities from 174 to 596 gpd per square foot; and specific capacities from 1.7 to 11 gpm per foot. Two determinations of the coefficient of storage were 0.0007 and 0.0002.

Tests were made in two wells completed in the Evangeline aquifer. The coefficients of transmissibility were 32,000 and 36,000 gpd per foot and coefficients of permeability were 244 and 327 gpd per square foot. The coefficient of storage was 0.00003. The specific capacity of one of the wells was 16.2 gpm per foot. These results compare favorably with those observed in nearby areas. Tests of the "heavily pumped layer" (Evangeline aquifer) in the Houston district show the average coefficient of permeability to be about 250 gpd per square foot, and tests in Jasper and Newton Counties northeast of the report area showed an average of 260 gpd per square foot.

PRODUCTION AND USE OF GROUND WATER

The first production of ground water in Chambers and Jefferson Counties was probably from holes dug into beach ridges by Indians who hunted and fished along the Gulf Coast. Early permanent settlers of the region utilized mostly shallow wells. Deussen (1914) reported many deep, fairly large wells, most of which flowed. These wells had been drilled in the decades preceding and following 1900. Oil exploration together with the development of rice irrigation in southeastern Texas and southern Louisiana caused many wells to be drilled. The extent and quality of the ground water were fairly well known at that time.

Penn Livingston and G. H. Cromack (written commun., 1943) reported that in Jefferson County, production of ground water, stimulated by oil field development, irrigation, and the construction of refineries, rose to a peak of about 25 mgd in 1926. Much of this development was in areas underlain mostly by slightly or moderately saline water. The poor quality of much of the water probably discouraged its use as production decreased to about 10 mgd in 1927. In 1941, the combined production in Chambers and Jefferson Counties was probably a little less than 8.5 mgd. Total production of ground water in both counties decreased to about 5 mgd in 1948. Development of the upper unit of the Chicot aquifer in the Winnie-Hamshire, Anahuac, and Hankamer areas; of the Evangeline and Chicot

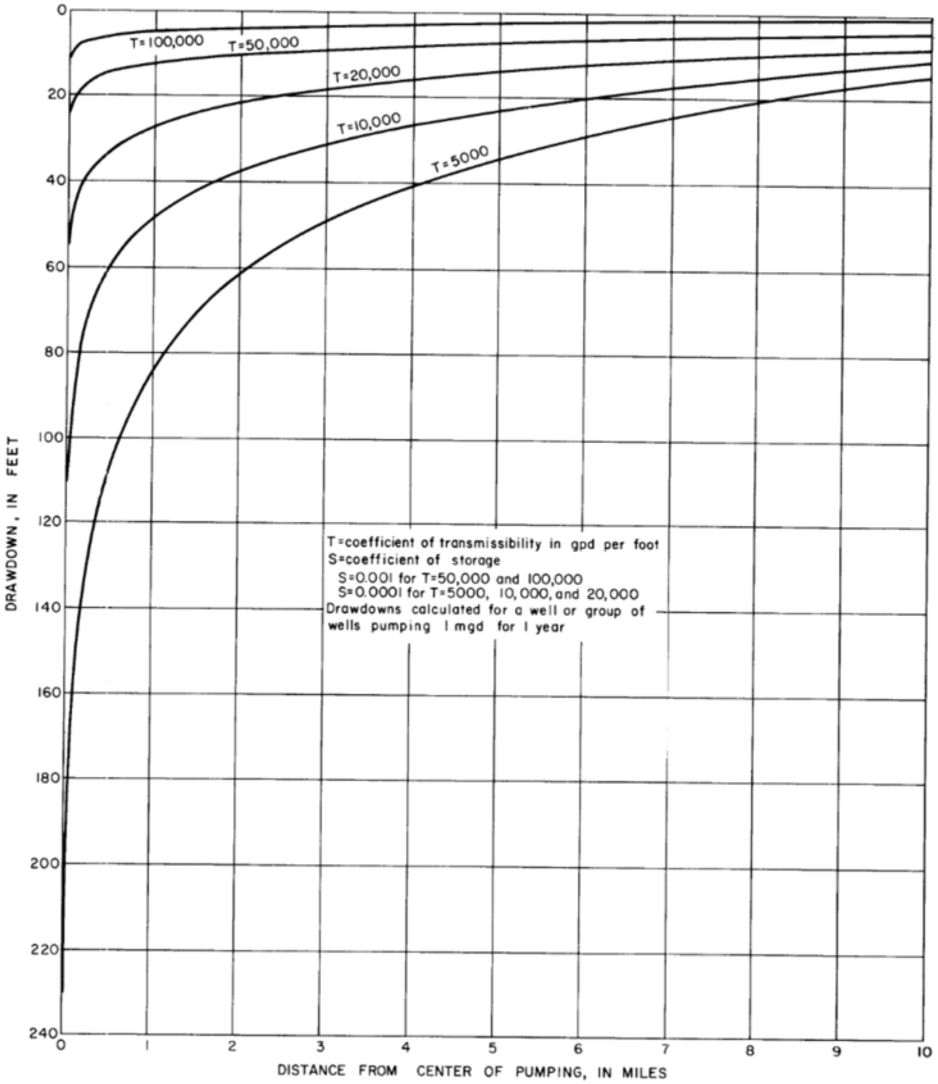

Figure 5.—Relation of Drawdown to Transmissibility and Distance

aquifers in the Mont Belvieu-Baytown area; and of the lower Chicot in the Beaumont-Port Arthur area raised the production rate to 8.6 mgd by 1965.

Most of the ground water developed prior to World War II was taken from the lower unit of the Chicot aquifer in the Beaumont-Port Arthur area, whereas production in 1965 was divided about equally among the upper unit of the Chicot, lower unit of the Chicot, and the Evangeline. The principal areas of production are the Mont Belvieu-Baytown area of western Chambers County, the Winnie-Hamshire area of Chambers and Jefferson Counties, and the Beaumont-Port Arthur area of Jefferson County. Other sites where significant ground-water withdrawals occur include the Big Hill Dome, the flank of High Island Dome, Redfish Reef in Galveston Bay, Hankamer, and Anahuac. The locations of wells in Chambers and Jefferson Counties and adjacent areas are shown on Figure 24.

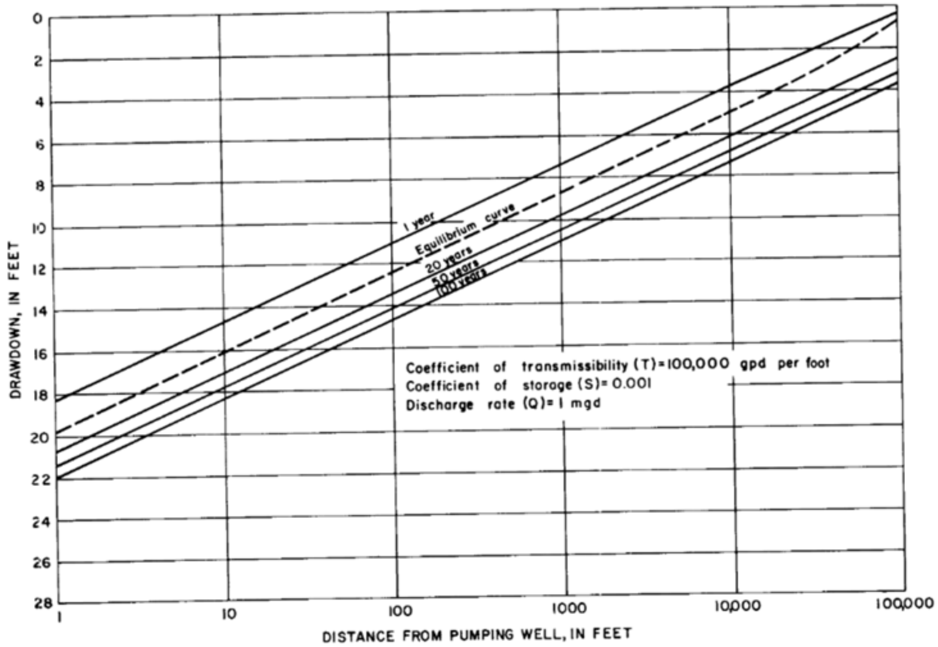

Figure 6.—Relation of Drawdown to Distance and Time as a Result of Pumping Under Artesian Conditions

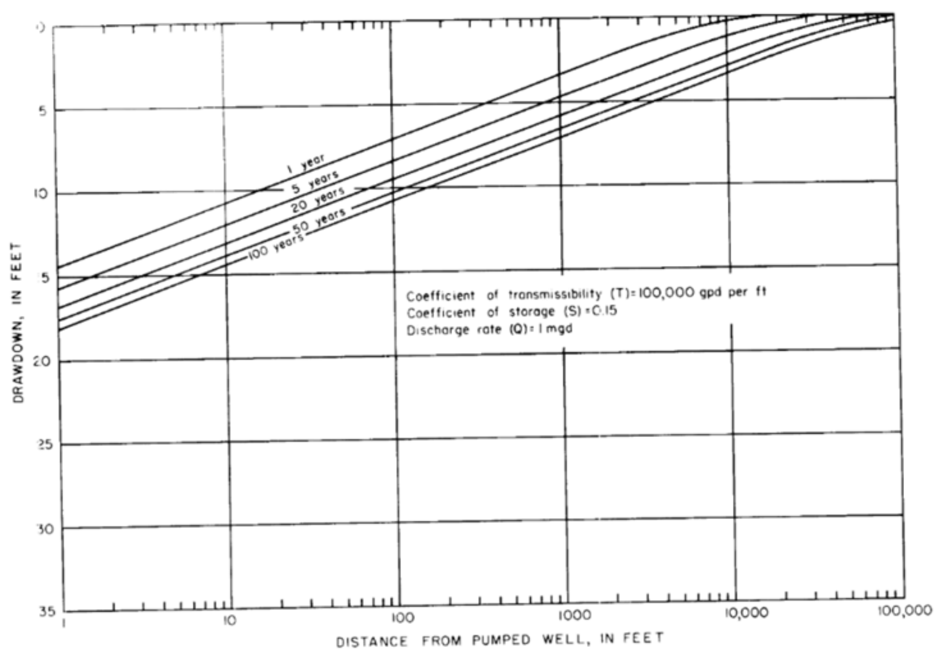

Figure 7.—Relation of Drawdown to Distance and Time as a Result of Pumping Under Water-Table Conditions

Table 2.—Summary of Aquifer Tests

WELL	DATE	COEFFICIENT OF TRANSMISSIBILITY (GPD PER FT)	COEFFICIENT OF PERMEABILITY (GPD PER FT^2)	COEFFICIENT OF STORAGE	SPECIFIC CAPACITY (GPM PER FT OF DRAWDOWN)	REMARKS
UPPER UNIT OF CHICOT AQUIFER						
DH-64-11-801	Dec. 3, 1955	15,000	375	–	11	100 minutes pumping time; recovery pumped well.
DH-64-12-102	July 12, 1966	29,800	*596	–	7	Recovered 100 minutes after 28 hours pumping.
DH-64-13-601	Sept. 16, 1953	10,800	360	–	5.3	5-hour recovery after 48 hours pumping.
DH-64-13-602	Oct. 2, 1953	11,800	358	–	8.3	5-hour recovery after 51 hours pumping.
PT-64-14-407	June 1, 1945	26,000	222	–	6.2	Recovery after 24 hours pumping.
PT-64-14-408	June 21, 1945	17,900	174	7.0×10^{-4}	–	Drawdown observation well.
PT-64-14-409	June 1, 1945	21,000		2.0×10^{-4}	–	Do.
PT-64-15-704	Sept. 22, 1966	21,300	207	–	–	Recovery observation well.
PT-64-15-705	–	21,600	216	–	1.7	Recovery pumped well; 23-hour test.
LOWER UNIT OF CHICOT AQUIFER						
PT-61-64-501	1941	55,200	502	–	–	Recovery after unknown period of pumping.
PT-61-64-502	Mar. 22, 1966	13,100	108	–	8.7	40-hour recovery following 27-hour drawdown.
PT-61-64-503	Mar. 21, 1966	18,000	310	4×10^{-4}	–	Observation well; drawdown.
PT-61-64-505	Mar. 24, 1966	183,000	915	–	32.5	Recovery pumped well after 22 hours pumping.

Table 2.–Summary of Aquifer Tests–Continued

WELL	DATE	COEFFICIENT OF TRANSMISSIBILITY (GPD PER FT)	COEFFICIENT OF PERMEABILITY (GPD PER FT^2)	COEFFICIENT OF STORAGE	SPECIFIC CAPACITY (GPM PER FT OF DRAWDOWN)	REMARKS
LOWER UNIT OF CHICOT AQUIFER–Continued						
PT-61-64-506	Mar. 24, 1966	163,000	906	1.06×10^{-3}	–	Drawdown test in observation well.
PT-61-64-509	Mar. 21, 1966	30,800	296	7×10^{-4}	–	Drawdown observation well.
DH-64-09-301	Nov. 3, 1966	78,200	821	–	25.8	25 hours recovery after 27 hours pumping.
DH-64-09-302	do	80,000	762	3.7×10^{-3}	–	Recovery of observation well.
DH-64-26-701	Nov. 29, 1966	5,200	157	–	3.4	5-hour recovery after 24 hours pumping.
DH-64-29-502	Aug. 22, 1966	401,000	1,670	–	11.0	130-minute recovery after 24 hours pumping.
LOWER UNIT OF CHICOT AQUIFER AND EVANGELINE AQUIFER						
DH-64-10-401	Aug. 3, 1955	45,000	–	–	23.2	Recovered 70 minutes after 5 days pumping.
EVANGELINE AQUIFER						
DH-64-09-305	May 27, 1966	32,000	244	–	16.2	300-minute recovery of constantly pumped well.
DH-64-09-307	do	36,000	327	3.0×10^{-5}	–	Recovery observation well.

* Permeability based on screen length.

The production of water from wells in Chambers and Jefferson Counties in 1965 was as follows (figures are in mgd):

COUNTY	CLASS OF USE INDUS-TRIAL	MUNICIPAL	IRRIGA-TION	TOTAL*
Jefferson	3.1	1.0	.5	4.6
Chambers	2.0	1.0	1.0	4.0
Total*	5.1	2.0	1.5	8.6

* Figures are approximate because some of the production was estimated.

About 30 percent of this production (about 2.5 mgd) was slightly or moderately saline water used by industry.

The high salinity of much of the ground water has restricted its use. Consequently, the primary sources of water have been the Neches and Trinity Rivers, and most of the needs of industry, irrigation, and large municipalities in the area from the mid-1920's until the 1950's were met from these sources. However, the consistent quality and uniform temperature of ground water was especially desirable for some uses and as early as the 1920's, ground water produced from the lower unit of the Chicot aquifer in Orange County was imported by a refinery in the Port Arthur area.

The total estimated use of ground water (including imported ground water) in Chambers and Jefferson Counties in 1965 was approximately 18.6 mgd. Of this, 10 mgd was fresh water produced from wells in Hardin and Orange Counties and imported by the city of Beaumont and industries in Beaumont and Port Arthur. In 1958, Beaumont started supplementing its surface-water supply with ground water from a well field tapping the Evangeline aquifer in Hardin County, and in 1965 obtained 6 mgd from this field. According to Underwood Hill, Water Superintendent of Beaumont (personal commun., July 8, 1967), the city of Beaumont plans to expand its usage of ground water to 20 mgd by 1980.

Two industries in Beaumont and Port Arthur in 1965 imported 4 mgd of ground water produced from the lower unit of the Chicot aquifer in Orange County. One industry in Port Arthur has been importing about 0.5 mgd since the 1920's. The other developed its supply in 1962.

Because sufficient quantities of fresh ground water are not available locally and large supplies of fresh ground water are available nearby, further importation of fresh ground water from outside the counties is probable.

WATER LEVELS

Water-level data are presented by hydrographs and maps. Data gathered during the 1941-42 inventory and during inventories since 1942 were used in the preparation of Figures 8 and 9. Water-level measurements are presented in Tables 4 and 6.

Long-term records of water levels indicate the magnitude of the water-level changes that have occurred in the Chicot aquifer. Measurements show that in well PT-64-06-401 (Figure 9), the differences in the high and low water levels were less than 2 feet during the period of record 1941-66. The largest change in water levels occurred in the lower unit of the Chicot aquifer in western Chambers County in the area adjacent to the city of Baytown, where water levels dropped more than 90 feet during the period 1941-66. The 1966 measurements, compared with the early reports of flowing wells, indicate that water levels have declined at least 150 feet. No long-term water-level records are available for the Evangeline aquifer. Water levels have possibly declined as much in the Mont Belvieu area as the decline recorded in the lower unit of the Chicot in the Baytown area.

Evangeline Aquifer

Water-level measurements in wells completed in the Evangeline aquifer in Chambers and Jefferson Counties date back only a few years. The levels that have been measured are in the Mont Belvieu area, and these closely approximate the levels in the lower Chicot in the same area.

Chicot Aquifer

The water levels and other criteria used to separate the upper and lower units of the Chicot aquifer in most of Chambers and Jefferson Counties were not sufficient to separate the two units in a large area centered near the eastern edge of Trinity Bay in Chambers County. Inspection of the maps (Figures 10 and 11) and of the hydrographs of wells (Figure 9) shows that the declines and seasonal fluctuations of water levels have been less in this area than in the areas to the east and west of it.

Lower Unit

The map of the 1941 and 1966 water levels in the lower unit of the Chicot aquifer (Figure 10) shows large depressions in western Chambers County as early as

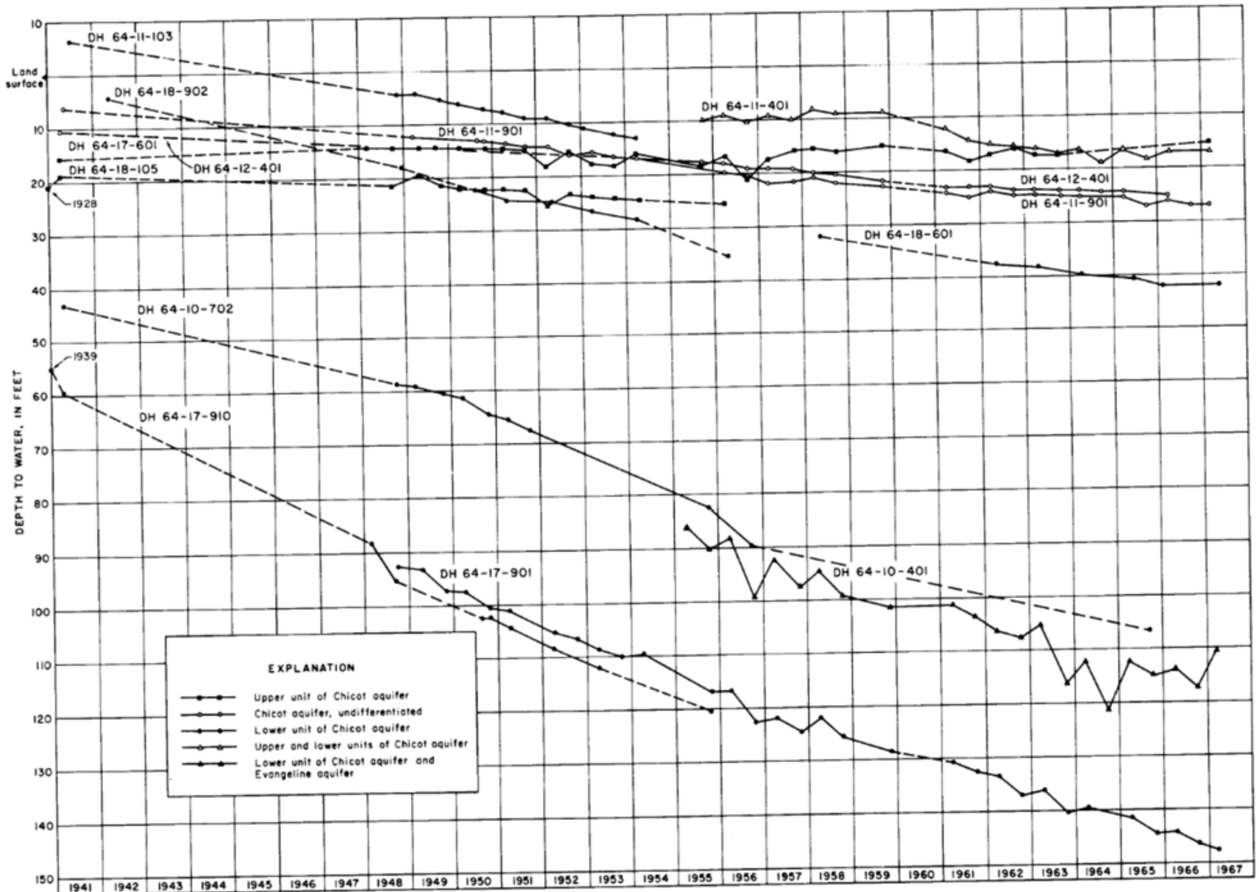

Figure 8
Changes in Water Levels in Wells Tapping Various Aquifers in Chambers County

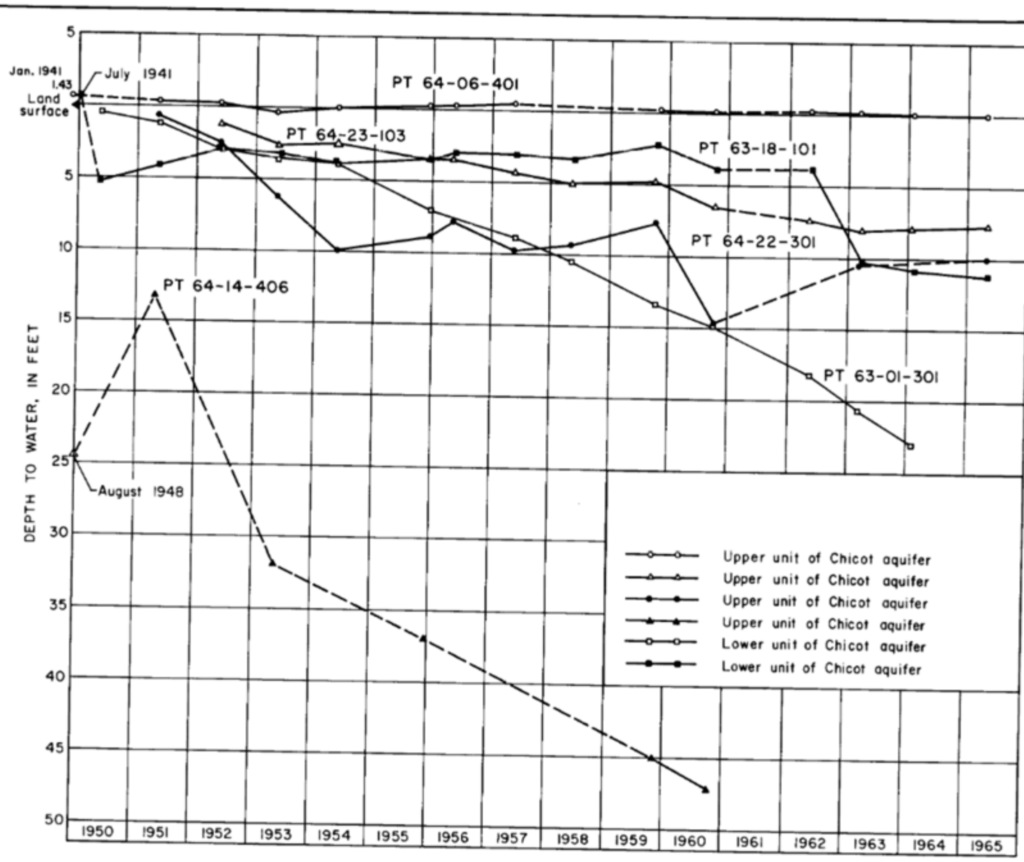

Figure 9

Changes in Water Levels in Wells Tapping the Upper and Lower Units of the Chicot Aquifer in Jefferson County

1941. These depressions were caused by heavy pumping in Galveston and Harris Counties. Contour lines on the map indicate that water in the lower unit of the Chicot aquifer was moving from western Chambers County into Harris and Galveston Counties in 1941. The direction of movement in 1966, as indicated by the map, is still the same, but the hydraulic gradient and the rate of movement have increased.

The effect of pumping from the lower Chicot in the Beaumont-Port Arthur-Orange area of eastern Jefferson and southern Orange Counties before 1941 is reflected in the shape of the contours. By 1966, the pumping center of this area was well defined. Pumping by chemical industries, municipalities, and from irrigation wells in Orange County caused a regional cone of depression that is reflected by the contours (Figure 10). The cone of depression extends into eastern Jefferson County, consequently, the movement of the water in this area is from Jefferson County into Orange County.

Upper Unit

The map of water levels in the upper unit of the Chicot aquifer in 1941 and 1966 (Figure 11) does not indicate any large regional centers of withdrawals in 1941. However, pumping depressed the water surface below sea level in areas a few miles west of Port Arthur and near Groves in Jefferson County and in the vicinity of Houston Point and Wallisville in Chambers County.

By 1966, the industrial, municipal, and irrigation withdrawals in the vicinity of Winnie had created a cone of depression (Figure 11) in eastern Chambers and western Jefferson Counties.

RELATION OF WATER-LEVEL DECLINES TO LAND-SURFACE SUBSIDENCE

The withdrawal of water from an artesian aquifer results in an immediate decrease in hydraulic pressure which partially supports the weight of the overlying rocks. With reduction in pressure, an additional load is transferred to the skeleton of the aquifer and a pressure difference between the sands and clays causes water to move from the clays to the sands. The entire process results in compaction of the sediments, most of which takes place in the clays. Because of the compaction, the land surface subsides.

Regional subsidence in the Texas Gulf Coast is due principally to the extraction of water, although subsidence may also occur because of the removal of oil and gas. In addition to other factors, the amount of decline in artesian head and the thickness of clay are important to total subsidence. R. K. Gabrysch (oral commun., 1967) found that in the Houston district, which includes the western part of Chambers County, subsidence ranged from 0.5 foot to 1.5 feet for each 100 feet of artesian head decline. The ratio of 0.5 foot subsidence per 100 feet head decline occurred in an area where the section contained about 40 percent clay. As the clay percentage increased, the ratio of subsidence to head decline increased. In the area of 1.5 feet subsidence per 100 feet head decline, clay composed about 70 percent of the section.

Winslow and Wood (1959) show that lowering of the artesian head by development of ground water has resulted in subsidence of the land surface in most of the upper Gulf Coast region of Texas. They mapped the extent of this subsidence by comparing measurements of bench-mark altitudes made at different times by the U.S. Coast and Geodetic Survey. Their map shows that the land surface subsided more than 0.5 foot in western Chambers County between 1918 and 1954. For this period of time, their map showed less than 0.25 foot subsidence for most of the rest of Chambers and Jefferson Counties. A small area in eastern Jefferson County had subsided more than 0.25 foot and an extremely local area, in the vicinity of the Spindletop Dome, subsided more than 1 foot. The areas that subsided, with the exception of the Spindletop Dome, are areas in which artesian head has declined. Subsidence at Spindletop is related to the production of oil. Extremely localized subsidence sometimes takes place when sulfur is removed from the cap rock of the salt domes by the Frasch process. A depression over 15 feet deep, which is periodically enlarging and deepening, is present at the Moss Bluff Dome on the Liberty-Chambers County line just east of the Trinity River. The Frasch process of removing sulfur has been initiated at the Fannett and Spindletop Domes in the last decade but noticeable subsidence that could be attributed to this cause was not found during this study.

The latest releveling of bench marks by the U.S. Coast and Geodetic Survey was in 1964, but only a part of the area mapped by Winslow and Wood was releveled. Gabrysch (1967) showed that subsidence in the western part of Chambers County has continued. Figure 12, a contour map of subsidence in the Houston district, shows that a maximum of 2 feet of subsidence occurred at the eastern edge of the city of Baytown (along the western edge of Chambers County) during the period 1943-1964. East of the area shown on Figure 12, regional subsidence through 1967 probably has been mostly less than 0.5 foot. In small areas, such as Lost Lake, Moss Bluff (north of Lost Lake), Hankamer, High Island, Big Hill (8 miles southeast), and Fannett, subsidence due to the removal of oil and gas probably is greater than 0.5 foot.

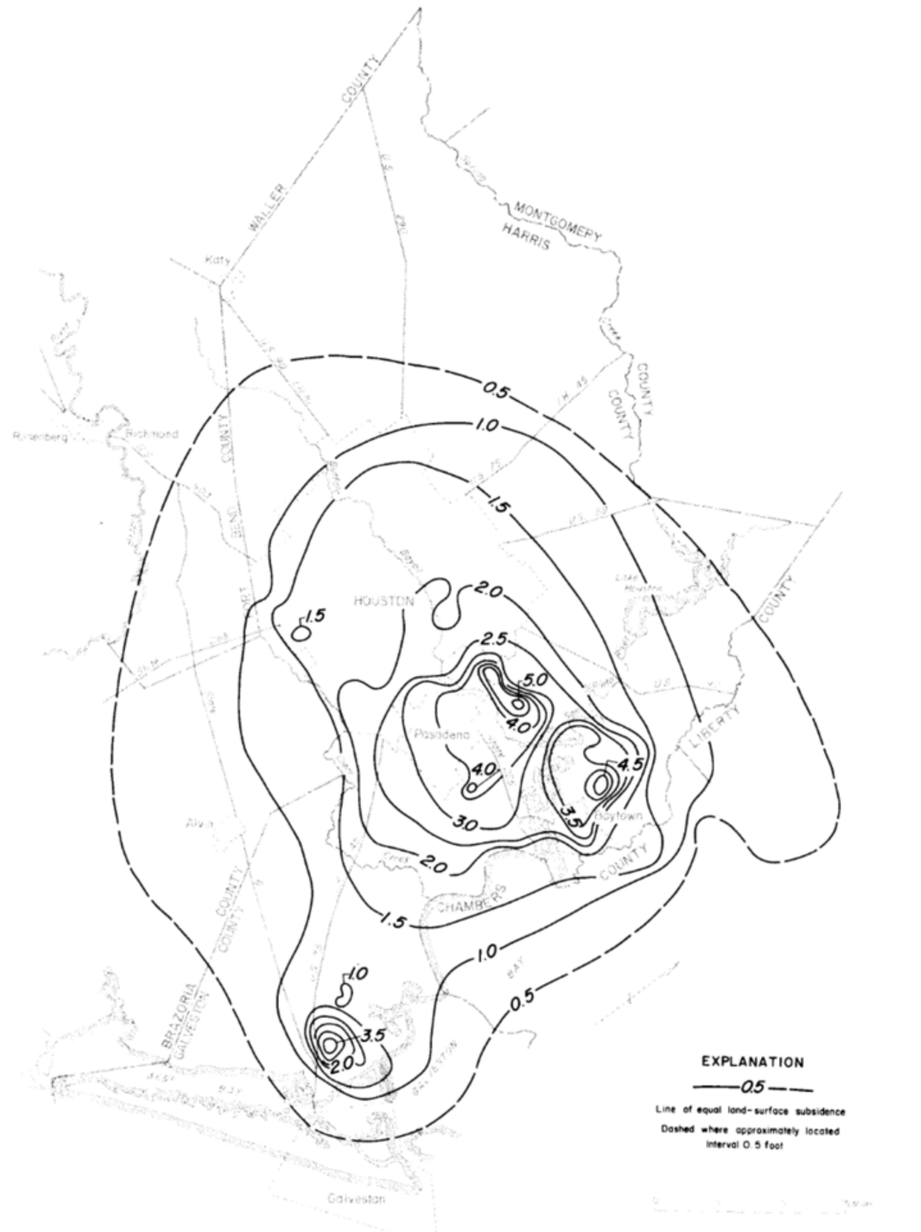

Figure 12
Subsidence of Land Surface in the Houston District, 1943-64

Gabrysch (1967, p. 33)

A sufficient number of bench marks, necessary to determine subsidence in detail, is not available in much of Chambers and Jefferson Counties.

WELL CONSTRUCTION

Generally, when a well is to be constructed for public supply or industrial use in a new location, a test hole is drilled to the depth desired. Formation samples are collected during drilling, and after completion of the test hole, an electrical log is run. The log is used to determine the occurrence of sands and to indicate in general the quality of water they contain. Some of these test holes are used to collect water samples for chemical analysis and to measure the water-yielding properties of the sands.

If favorable ground-water conditions are indicated by the data collected, the test hole is usually reamed to the top of the first sand that is to be screened; surface casing is then installed and cemented into place. The diameter of the surface casing in most large-capacity wells in Chambers and Jefferson Counties ranges from 12 to 20 inches.

The section to be screened is then reamed with the largest drilling bit that can pass through the surface casing. The hole is then underreamed by a device that expands and cuts a hole larger than the diameter of the surface casing, usually to a diameter of 30 inches. Blank pipe and screen are then installed with part of the blank pipe extending up into the surface casing. The bottom of the screen is closed off with a back-pressure valve that permits the use of fluid to keep the hole clean during emplacement of the screen, but prevents water, sand, or gravel from entering through the bottom. Gravel or sand is then pumped into the annular space between the screen and the well bore. The gravel reservoir—the space between the bottom of the surface casing and the top of the blank pipe—is also filled with gravel. The construction of a typical industrial or public-supply well is shown on Figure 13.

Usually the screen is steel pipe, 6 to 14 inches in diameter, that has been perforated and wrapped with stainless steel wire. Where corrosion is a problem, the pipe may be stainless steel. Generally the openings in the screen, which are as much as 0.05 inch wide, are larger than the sand particles in the formation but smaller than those of the gravel envelope. Blank pipe of the same diameter as the screen is used to separate screens and is positioned opposite clay beds in the producing intervals.

The well may be developed by surging, swabbing, pumping, back-washing, and by chemical treatment until the specific capacity of the well indicates complete development and the sand-water ratio is satisfactory. The final production test usually lasts from 4 to 24 hours, during which samples of water for chemical and bacterial analyses are collected.

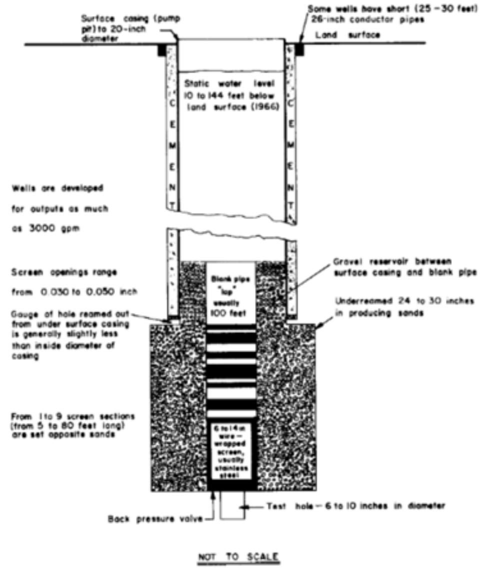

Figure 13.—Construction of Industrial and Public Supply Wells

Some large irrigation wells have been constructed in a similar manner, with slotted pipe being used instead of wrapped screen. More commonly, however, a large diameter hole is drilled from the surface to the finished depth, no cement is used, and gravel is placed outside the entire casing string. In some smaller diameter irrigation wells, screen is selected to fit the sands encountered, and no gravel is used.

The size and type of pump installed on the large-capacity wells depend upon the pumping lift and the quantity of water needed. The larger public-supply and industrial wells have high-capacity, deep-well turbine pumps powered by electricity. Irrigation wells are equipped with the same type of pumps but are powered by diesel or gas motors.

Although shallow dug wells, usually 30 to 36 inches in diameter, have been constructed in a few localities, most of the modern, small-capacity wells used for domestic or industrial supply are drilled wells that have been completed with a single screen.

A variety of screen types are available. Stainless steel and plastic have become the most widely used in Chambers and Jefferson Counties because of their resistance to corrosion. Plastic is coming into widespread use as the material for conductor pipe and screens in the small and relatively shallow wells. Stainless steel screen is used in the large wells.

Oil-rig drill pipe is used as casing in most of the water-supply wells drilled in the oil fields of Trinity Bay. Because of its thick walls, the time it takes the pipe to corrode and the well to fail is extended.

Various types of pumps are used on small-capacity wells. New small wells are usually equipped with submersible pumps, whereas older wells, particularly those in areas of lowered artesian head, are usually equipped with the deep jet-type pumps. Windmills in conjunction with cylinder-type pumps are still used to lift water for livestock use, particularly in remote locations, but many windmills are being replaced by electric-powered pumps.

QUALITY OF GROUND WATER

The chemical constituents of ground water originate principally from the soil and rocks through which the water has moved. Table 3 lists many of the chemical constituents and properties of water and discusses their source and significance. The chemical analyses of water from selected wells in Chambers and Jefferson Counties are given in Table 7.

The quality of water commonly determines its suitability for use. A general classification of water, according to dissolved-solids content in mg/l (milligrams per liter), is as follows (modified from Winslow and Kister, 1956, p. 5):

DESCRIPTION	DISSOLVED-SOLIDS CONTENT (MG/L)
Fresh	Less than 1,000
Slightly saline	1,000 to 3,000
Moderately saline	3,000 to 10,000
Very saline	10,000 to 35,000
Brine	More than 35,000

Maps showing the base of fresh water, the base of slightly saline water, and the thickness of sands containing fresh water are included in this report as Figures 16, 17, 18, and 19. Analysis of these maps and the cross sections (Figures 25 through 28) shows that most of the water underlying Chambers and Jefferson Counties is slightly or more than slightly saline.

Suitability for Public Supply

The U.S. Public Health Service (1962, p. 7) has established standards for the chemical quality of water to be used on common carriers engaged in interstate commerce. These standards, which are commonly used in evaluating public water supplies, are included in Table 3.

According to the U.S. Public Health Service (1962, p. 41), the optimum fluoride level for a given community depends on climatic conditions, because the amount of water (and consequently the amount of fluoride) ingested is influenced primarily by air temperature. In Chambers and Jefferson Counties, the optimum concentration based on the annual average of maximum daily air temperature of 26.1°C (79°F) at Beaumont is 0.8 mg/l. Presence of fluoride in average concentrations greater than twice the optimum value, or 1.6 mg/l, would constitute grounds for rejection of the supply. Excessive concentrations of fluoride are present in the water from some wells in Chambers and Jefferson Counties.

The 1941-42 well inventory and water-sampling program (Livingston and Cromack, 1942a, 1942b) included analyses of water from shallow wells (9 to 47 feet deep) in the upper unit of the Chicot aquifer that showed more than the recommended limit (45 mg/l) of nitrate concentration. However, the nitrate concentration in water from all deeper wells sampled at that time was less than the recommended limit. Samples from only a few shallow wells were collected in 1966. Of these, only one well (PT-64-08-403), 27 feet deep, yielded water with an excessive amount of nitrate. Also, the deeper wells sampled in 1966 did not have excessive nitrates. The presence of nitrates in excess of the limit in the shallow wells suggests pollution by sewage or by other organic material.

Water having a chloride content exceeding 250 mg/l may have a salty taste, and sulfate in water in excess of 250 mg/l may produce a laxative effect. Much of the water produced in Chambers and Jefferson Counties has a chloride content greater than 250 mg/l. Excessive amounts of sulfates occur in water in some shallow sands and in some of the deeper sands near the shallow salt domes.

About half of the samples analyzed for iron showed that this constituent was present in excess of the 0.3 mg/l limit. A relationship between iron concentration and depth of the well was not established, and it was not determined whether the iron occurred naturally or as a product of interaction between the water and the metal parts of the well.

Suitability for Industrial Use

The suitability of water for industrial use is dependent upon the process in which the water is used. Water for cooling and boiler uses should be noncorrosive and relatively free of scale-forming constituents, of which hardness and silica are the most important.

The silica content (Table 7) in water from the aquifers in these counties ranged from 5.3 to 38 mg/l. Moore (1940, p. 263) suggested the following allowable concentration of silica in boilers operating at various

Table 3.--Source and Significance of Dissolved-Mineral Constituents and Properties of Water

CONSTITUENT OR PROPERTY	SOURCE OR CAUSE	SIGNIFICANCE
Silica (SiO_2)	Dissolved from practically all rocks and soils, commonly less than 30 mg/l. High concentrations, as much as 100 mg/l, generally occur in highly alkaline waters.	Forms hard scale in pipes and boilers. Carried over in steam of high pressure boilers to form deposits on blades of turbines. Inhibits deterioration of zeolite-type water softeners.
Iron (Fe)	Dissolved from practically all rocks and soils. May also be derived from iron pipes, pumps, and other equipment. More than 1 or 2 mg/l of iron in surface waters generally indicates acid wastes from mine drainage or other sources.	On exposure to air, iron in ground water oxidizes to reddish-brown precipitate. More than about 0.3 mg/l stains laundry and utensils reddish-brown. Objectionable for food processing, textile processing, beverages, ice manufacture, brewing, and other processes. U.S. Public Health Service (1962) drinking-water standards state that iron should not exceed 0.3 mg/l. Larger quantities cause unpleasant taste and favor growth of iron bacteria.
Calcium (Ca) and magnesium (Mg)	Dissolved from practically all soils and rocks, but especially from limestone, dolomite, and gypsum. Calcium and magnesium are found in large quantities in some brines. Magnesium is present in large quantities in sea water.	Cause most of the hardness and scale-forming properties of water; soap consuming (see hardness). Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, and in textile manufacturing.
Sodium (Na) and potassium (K)	Dissolved from practically all rocks and soils. Found also in ancient brines, sea water, industrial brines, and sewage.	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers and a high sodium content may limit the use of water for irrigation.
Bicarbonate (HCO_3) and carbonate (CO_3)	Action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.	Bicarbonate and carbonate produce alkalinity. Bicarbonates of calcium and magnesium decompose in steam boilers and hot water facilities to form scale and release corrosive carbon dioxide gas. In combination with calcium and magnesium, cause carbonate hardness.
Sulfate (SO_4)	Dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Commonly present in mine waters and in some industrial wastes.	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts, sulfate in combination with other ions gives bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process. U.S. Public Health Service (1962) drinking-water standards recommend that the sulfate content should not exceed 250 mg/l.
Chloride (Cl)	Dissolved from rocks and soils. Present in sewage and found in large amounts in ancient brines, sea water, and industrial brines.	In large amounts in combination with sodium, gives salty taste to drinking water. In large quantities, increases the corrosiveness of water. U.S. Public Health Service (1962) drinking-water standards recommend that the chloride content should not exceed 250 mg/l.
Fluoride (F)	Dissolved in small to minute quantities from most rocks and soils. Added to many waters by fluoridation of municipal supplies.	Fluoride in drinking water reduces the incidence of tooth decay when the water is consumed during the period of enamel calcification. However, it may cause mottling of the teeth, depending on the concentration of fluoride, the age of the child, amount of drinking water consumed, and susceptbility of the individual. (Maier, 1950)
Nitrate (NO_3)	Decaying organic matter, sewage, fertilizers, and nitrates in soil.	Concentration much greater than the local average may suggest pollution. U.S. Public Health Service (1962) drinking-water standards suggest a limit of 45 mg/l. Waters of high nitrate content have been reported to be the cause of methemoglobinemia (an often fatal disease in infants) and therefore should not be used in infant feeding. Nitrate has been shown to be helpful in reducing inter-crystalline cracking of boiler steel. It encourages growth of algae and other organisms which produce undesirable tastes and odors.
Dissolved solids	Chiefly mineral constituents dissolved from rocks and soils. Includes some water of crystallization.	U.S. Public Health Service (1962) drinking-water standards recommend that waters containing more than 500 mg/l dissolved solids not be used if other less mineralized supplies are available. Waters containing more than 1000 mg/l dissolved solids are unsuitable for many purposes.
Hardness as $CaCO_3$	In most waters nearly all the hardness is due to calcium and magnesium. All the metallic cations other than the alkali metals also cause hardness.	Consumes soap before a lather will form. Deposits soap curd on bathtubs. Hard water forms scale in boilers, water heaters, and pipes. Hardness equivalent to the bicarbonate and carbonate is called carbonate hardness. Any hardness in excess of this is called non-carbonate hardness. Waters of hardness as much as 60 ppm are considered soft; 61 to 120 mg/l, moderately hard; 121 to 180 mg/l, hard; more than 180 mg/l, very hard.
Specific conductance (micromhos at 25°C)	Mineral content of the water.	Indicates degree of mineralization. Specific conductance is a measure of the capacity of the water to conduct an electric current. Varies with concentration and degree of ionization of the constituents.
Hydrogen ion concentration (pH)	Acids, acid-generating salts, and free carbon dioxide lower the pH. Carbonates, bicarbonates, hydroxides, and phosphates, silicates, and borates raise the pH.	A pH of 7.0 indicates neutrality of a solution. Values higher than 7.0 denote increasing alkalinity; values lower than 7.0 indicate increasing acidity. pH is a measure of the activity of the hydrogen ions. Corrosiveness of water generally increases with decreasing pH. However, excessively alkaline waters may also attack metals.

pressures: less than 150 psi (pounds per square inch), 40 mg/l; 150-250 psi, 20 mg/l; 250-400 psi, 5 mg/l; and more than 400 psi, 1 mg/l.

A classification commonly used with reference to hardness is as follows: 60 mg/l or less, soft; 61 to 120 mg/l, moderately hard; 121 to 180 mg/l, hard; and more than 180 mg/l, very hard. If water used in steam boilers has more than 75 mg/l hardness as calcium carbonate, it should be treated to prevent the formation of scale (American Society for Testing Materials, 1959, p. 24). In high-pressure boilers, the tolerance is much less than 75 mg/l. Suggested water-quality tolerances for a number of industries are summarized by Hem (1959, p. 253) from Moore (1940). Although the hardness of the water (Table 7) ranges from soft to very hard, most of the water sampled was moderately hard or hard.

Large amounts of water are used to dissolve salt from salt domes to create caverns for storage of gas; the quality of water used for this purpose is not important. In some chemical processes, water of uniform chemical quality, clarity, and temperature is necessary, and even slightly or moderately saline ground water often meets these conditions better than surface water. In water-flooding operations, saline ground water is often preferred because of its compatability with fluids in the formation and because it is usually organically pure and sediment-free.

The temperature of water is often of great importance to industry and to other users. The temperature of ground water near the land surface is approximately the same as the mean annual air temperature of the region, 20.9°C (69.7°F) at Beaumont, but increases with depth. The lowest temperature of ground water recorded during the study, from a well 159 feet deep, was 22°C (71°F). The highest water temperature recorded during the study, from a well 1,255 feet deep, was 29.2°C (84.6°F). Temperature of ground water at any particular depth remains relatively constant throughout the year.

Suitability for Irrigation

The suitability of water for irrigation depends on the chemical quality of the water and on other factors such as soil texture and composition, types of crops, irrigation practices, and climate. The most important chemical characteristics pertinent to the evaluation of water for irrigation are: the proportion of sodium to total cations—an index of the sodium hazard; total concentration of soluble salts—an index of the salinity hazard; RSC (residual sodium carbonate); and the concentration of boron.

A system of classification commonly used for judging the quality of water for irrigation was proposed by the U.S. Salinity Laboratory Staff (1954, p. 69-82). This classification is based primarily on the salinity hazard as measured by the electrical conductivity of the water and on the sodium hazard as measured by the SAR (sodium-adsorption ratio). Although this classification was used in Figure 14, it may not be directly applicable because of the high rainfall. Wilcox (1955, p. 15-16) stated that water would be safe for supplemental irrigation if its conductivity was less than 2,250 micromhos per centimeter at 25°C and if its SAR was less than 14. This classification does show that in Chambers and Jefferson Counties most water tested had a high to very high salinity hazard and a low to very high sodium hazard. However, of the 62 water samples represented on the diagram, 30 samples were within the safe limits for supplemental irrigation. Most of these samples were taken from the freshest portions of the aquifers and the 32 samples which showed the water to be probably unsafe for even supplemental irrigation are probably most representative of most of the water in the aquifers of Chambers and Jefferson Counties.

An excessive concentration of boron renders a water unsuitable for irrigation. Scofield (1936, p. 286) indicated that boron concentrations of as much as 1 mg/l are permissible for irrigating most boron-sensitive crops and that concentrations of as much as 3 mg/l are permissible for the more boron-tolerant crops. All but one analysis (Table 7) which list boron show a concentration less than 1 mg/l.

Another factor in assessing the quality of water for irrigation is the RSC of the water. Excessive RSC will cause water to be alkaline, and the alkaline water will cause organic material of the soil to dissolve. The affected soil, which may become grayish-black, is referred to as "black alkali". Wilcox (1955, p. 11) states that laboratory and field studies have resulted in the conclusion that water containing more than 2.5 me/l (milliequivalents per liter) RSC is not suitable for irrigation. Water containing from 1.25 to 2.5 me/l is marginal, and water containing less than 1.25 me/l RSC is probably safe. Correct irrigation practices and proper use of amendments to the soil might make possible the successful use of marginal water for irrigation. In the majority of the samples analyzed, the RSC was high, the maximum value being 9.31 me/l.

The high conductivity (salinity hazard) and the generally unfavorable SAR and RSC values shown in the analyses are probably among the factors responsible for the abandoning of numerous irrigation wells in Chambers and Jefferson Counties in the past.

RELATIONSHIP OF FRESH GROUND WATER TO SALINE GROUND WATER

Two distinct relationships between fresh and saline water are evident in the Chicot and Evangeline aquifers in Chambers and Jefferson Counties. The normal relationship is for the fresh water to float on the salt water because of the greater density of the latter. This

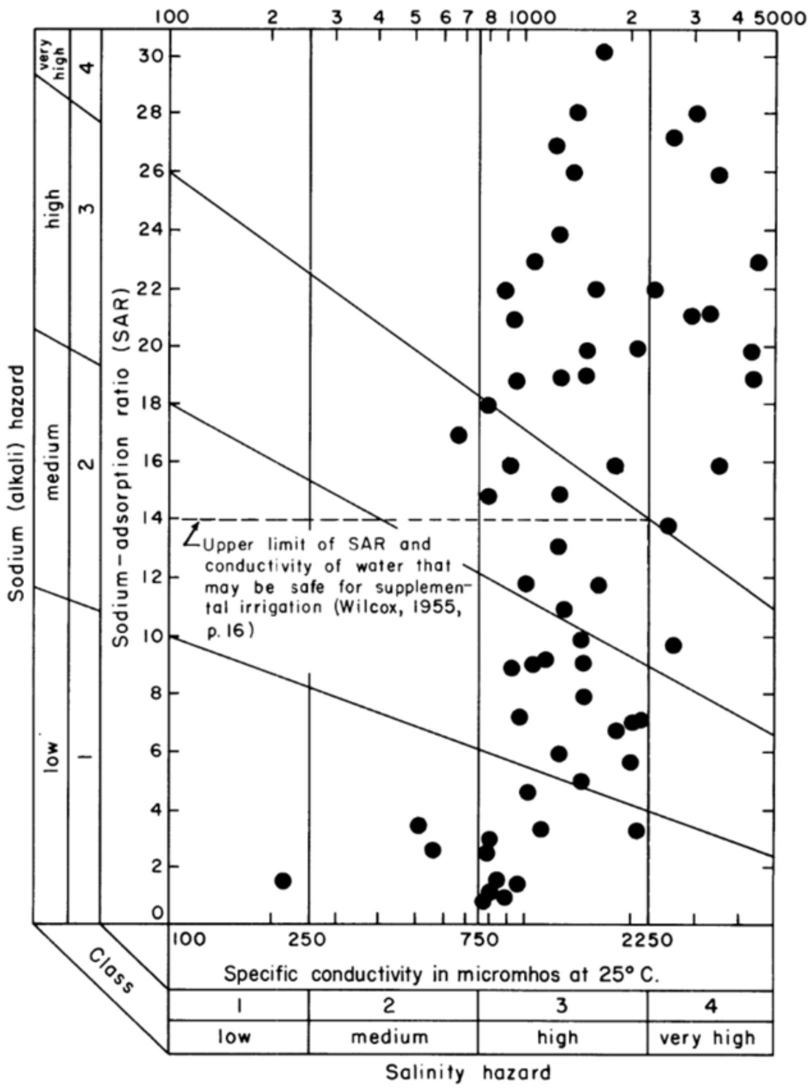

Figure 14

Classification of Irrigation Waters

relationship is modified by the interbedding of sands and clays. Fresh water occurs at depths greater than 1,400 feet under these conditions in Chambers and Jefferson Counties.

The other relationship occurs in the vicinity of the salt domes. The domes are composed of about 90 to 95 percent rock salt and 5 to 10 percent impurities, most of which is anhydrite (Hanna, 1958, p. 7). These domes have penetrated the sands and clays and placed soluble salt in contact with the water in the aquifers.

Originally, the shallowest and most permeable aquifer, the Chicot, had the lowest artesian head. Saline water has entered the lower beds of the Chicot aquifer near the domes that penetrate it. Saline water has also deteriorated the quality of the water in the Evangeline aquifer, near these domes.

When water dissolved the salt near the top and along the sides of the domes, much of the impurities in the salt remained as residue. Most of this residue was left at the top of the domes, where it became the parent material for the cap rock. Portions of this anhydrite have been altered to gypsum, lime, and sulfur. The high sulfate concentrations found in the analysis of some water from the Chicot in the vicinity of the domes probably originates from processes taking place in the cap rock.

Figure 4, a block diagram and hydrologic section showing the relationship of the ground water and its quality to the Barber's Hill Dome at Mont Belvieu, indicates that the poorer quality water in the lower unit of the Chicot aquifer can be traced from the dome to the northeastern edge of Baytown (6 miles away). Electric logs indicate that a similar relationship exists in the Nome area of Jefferson County, south of the Sour Lake Dome in Hardin County.

Sands that crop out north of the Fannett Dome, in the vicinity of the town of Fannett, contain only saline water even at very shallow depths. Because the area is topographically higher than the surrounding area, these sands should contain fresh water. The presence of saline water is probably a result of deeper artesian saline water flowing upward around the periphery of the dome and discharging into the shallower sands. Before well development, surface springs or seeps probably discharged some of this water.

DISPOSAL OF OIL-FIELD BRINES AND OTHER CONTAMINANTS

According to a 1961 salt-water inventory, about 60.4 million barrels of oil-field brine was produced during 1961 in Chambers and Jefferson Counties. Of this quantity, 66 percent was returned to saline water-bearing formations by injection wells, 26 percent was released to surface-water courses, 7.5 percent was disposed of in open pits, and 0.5 percent was disposed of by miscellaneous or "unknown" processes (Texas Water Commission and Texas Water Pollution Control Board, 1963, p. 46-86 and 258-287).

The method of disposal of least danger to fresh ground-water supplies is injection through properly constructed wells; probably the most dangerous method is disposal of the brine in open pits. In Chambers and Jefferson Counties, the average annual precipitation is 54 inches and the average annual gross lake-surface evaporation is 47 inches. To be effective in brine disposal, the open pit must be constructed in sandy soil. Such construction allows the brine to seep into the ground, thereby contaminating the ground water. Most open pits are constructed in clay soil and act as holding or storage ponds. They may fill and overflow to the nearest stream or area of sandy soil.

Although contamination of ground water has probably occurred in places from the disposal of oil-field brines, no known large-scale damage to the ground-water supplies of Chambers and Jefferson Counties has occurred. Dead trees and other vegetation noted in the vicinity of old brine pits were probably killed by brine that overflowed or seeped out of the pits. In most of these areas, injection wells have replaced pits. Many injection wells have been drilled since the 1961 salt-water inventory, and the ratio of pit to injection-well disposal is constantly improving.

Large quantities of saline waste water are produced by industry in the vicinity of salt domes and large quantities of waste water are released in these and in other industrial areas. Much of this water comes from sulfur mining and from the construction of storage chambers in salt domes. Facilities to gather and hold the waste water exist at most domes. At some locations this water is injected back into the subsurface, but at most locations ditches carry this water to large holding ponds or lakes from which the water is released to the surface-water courses of the area. Controlled releases from these lakes are made so as to minimize the effect on natural waters.

Contamination of the shallow ground water probably takes place in the vicinity of many of the gathering, holding, and release systems that are excavated in the surface formations, Those in clay probably do not need lining, but those systems in sandy soil are probably contributing inferior quality water to an already limited source of fresh ground water.

Most towns and industries dispose of their effluent in the tidal portion of the streams or into the bays, which already contain saline water. The most harmful effect of this practice is that under certain conditions this effluent kills fish and wildlife, and the effluent often imparts noxious odors and colors to the streams and bays.

PROTECTION OF WATER QUALITY IN OIL-FIELD DRILLING OPERATIONS

The Railroad Commission of Texas requires that contractors drilling oil and gas wells use casing and cement tc protect fresh-water strata from contamination. For more than the past decade, the Railroad Commission has received recommendations from the Texas Water Development Board and from its predecessors, the Texas Water Commission and the Texas Board of Water Engineers, concerning the depths to which the water should be protected.

Where oil or gas fields are established, the recommended depths are incorporated in some of the field rules. Figure 15 shows the amount of surface casing required by the Oil and Gas Division of the Railroad Commission of Texas and the depth of slightly saline water in those fields in Chambers and Jefferson Counties having surface-casing requirements. Figure 16 is a map showing the approximate altitude of the base of slightly saline water.

AVAILABILITY OF GROUND WATER

Evangeline Aquifer

The Evangeline aquifer contains fresh water only in parts of western Chambers County and northern Jefferson County. Assuming a porosity of 30 percent, about 2,600,000 acre-feet of fresh water is stored in western Chambers County and about 800,000 acre-feet of fresh water is stored in northern Jefferson County; however, only a small part of this water could be recovered because of specific retention of much of this water and because of encroachment of nearby salt water. The fresh water extends to depths greater than 1,400 feet below sea level in western Chambers County and to depths of more than 1,000 feet below sea level in northern Jefferson County. Areas where fresh water occurs in the Evangeline aquifer underlie less than 10 percent of the combined areas of these counties. The maximum thicknesses of fresh-water sands is greater than 400 feet in Chambers County and greater than 200 feet in Jefferson County (Figure 17). Several large capacity industrial wells are completed in the Evangeline on the southwest flank of the Barbers Hill Dome. One irrigation well, in the Houston Point area of Chambers County, is completed in the Evangeline and lower unit of the Chicot.

Wells yielding 1,000-3,000 gpm could be constructed in northwestern Chambers County where sands in the Evangeline contain fresh water to depths approaching 1,500 feet below sea level.

Some sands of the Evangeline aquifer contain fresh water in parts of the Houston Point area. These sands and the Chicot sands above them are currently being tested and evaluated by the industries that are establishing new plants. Limited uses for sanitary purposes and boiler-feed water are planned. Wells yielding 100-1,000 gpm from the Evangeline aquifer could be developed in this area. The proximity of slightly saline water in the same beds in this area will probably preclude any large scale development of this water as a dependable source.

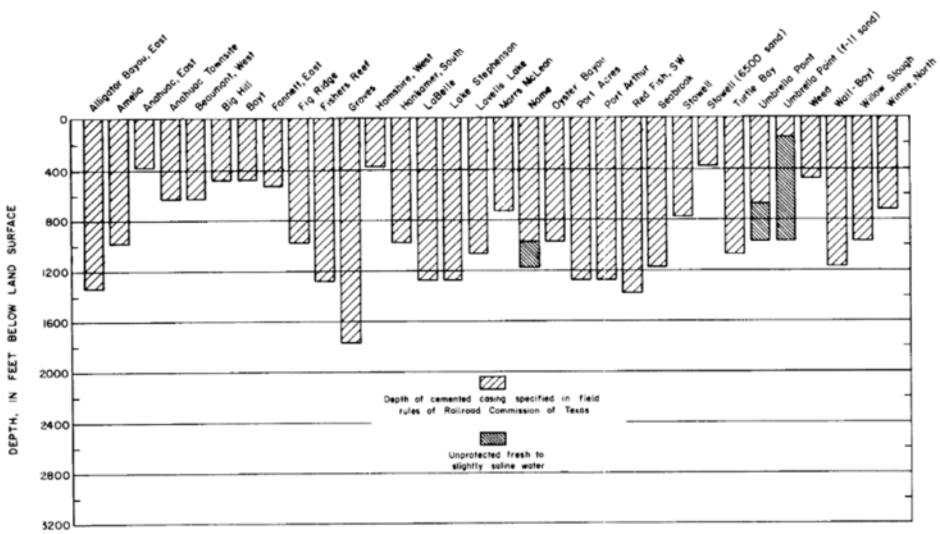

Figure 15.—Comparison Between Surface-Casing Requirements in Oil Fields and Depth of Base of Sands Containing Fresh to Slightly Saline Water

Chicot Aquifer

Lower Unit

The approximate base and thickness of the fresh-water sands in the lower unit of the Chicot aquifer are shown on Figure 18. The lower unit of the Chicot contains fresh water in the Houston Point, Mont Belvieu, and Galveston Bay areas of Chambers County and in a small area along the eastern boundary of Jefferson County. The deepest occurrence of fresh water is in western Chambers County where fresh water extends to depths of more than 800 feet below sea level. Here the net thickness of sands containing fresh water is greater than 100 feet. In Jefferson County the maximum sand thickness is less than 50 feet. Fresh water in this aquifer underlies about a third of Chambers County and less than 5 percent of Jefferson County.

In the Houston Point and Mont Belvieu areas of northwestern Chambers County, the only place in which the lower unit of the Chicot has not been affected by saline water from Barbers Hill Dome is northwest of the dome. In this small area, all of the water in the aquifer is fresh. Large capacity wells that would produce fresh water could be constructed here.

The town of Mont Belvieu is using two public-supply wells (DH-64-09-301 and DH-64-09-302) near the saline water. Water from the public-supply wells will probably become more saline as pumping continues.

Assuming a porosity of 30 percent, almost 4,000,000 acre-feet of fresh water is stored in the lower unit of the Chicot aquifer in Chambers County, 2,900,000 acre-feet of which underlies 150 square miles of Galveston Bay. Only a small part of these quantities could be pumped, however, because of specific retention of much of the water and because of encroachment of nearby salt water.

About 150,000 acre-feet of fresh water is stored in the lower unit of the Chicot aquifer in Jefferson County. The wells tapping this fresh-water supply are all near the interface of the fresh water with the slightly saline water. Extensive development of additional fresh water will cause saline water to move into the wells. Many of the wells developed in this aquifer in eastern Jefferson County already produce slightly or moderately saline water which is used by industry for cooling and fire protection. Wells that produce up to 3,000 gpm have been developed in the aquifer, and additional wells of this capacity can be constructed.

Generally, more than 100 feet of saturated sand containing slightly to moderately saline water is present in most places, and in a large area along the southern boundaries of the counties, massive beds in the aquifer total more than 500 feet in thickness. Large (tens of mgd) sustained withdrawals of moderately saline water could be made in most areas of the two counties without excessive drawdown in water levels.

Upper Unit

The most widespread aquifer containing fresh water in Chambers and Jefferson Counties is the upper unit of the Chicot. Generally, it contains fresh water in and beyond the same areas as the lower unit of the Chicot and the Evangeline aquifers. However, in over 50 percent of Chambers and Jefferson Counties, only small supplies can be developed in this aquifer. Individual sand beds range in thickness from several feet to about 50 feet. Wells produce or have produced up to 1,000 gpm of fresh water from this aquifer in the Houston Point area of eastern Chambers County, at Anahuac, and in a fairly large area centered at Winnie. Additional fresh-water wells can be constructed in this aquifer in these areas of Chambers County and in extreme northern Jefferson County without an immediate threat of water-quality deterioration.

Throughout much of Chambers and Jefferson Counties water of poorer quality underlies or occurs at short distances from many of the producing wells. With continued pumpage, some of these wells probably will produce poorer quality water.

The approximate altitude of the base of fresh water in the upper unit of the Chicot aquifer is shown in Figure 19. The deepest occurrence of fresh water is in the northernmost part of Jefferson County where the base is greater than 200 feet below sea level. The base of fresh water becomes more shallow to the south and is only a few feet below sea level in the central and southern parts of Chambers and Jefferson Counties.

QUATERNARY GEOLOGY

By

Saul Aronow

Geologic field studies in southeastern Texas that contributed to the preparation of this report were supported by grants from the National Science Foundation, Lamar Tech Research Center, and Sigma Xi.

Most of the systematic field work was done as part of the Geologic Atlas of Texas project of the Bureau of Economic Geology of the University of Texas. The geologic map of Chambers and Jefferson Counties (Figure 20) was adapted from preliminary copies of the Houston and Beaumont sheets of the Geologic Atlas (Bureau of Economic Geology, 1968a and 1968b).

The Soil Conservation Service of the U.S. Department of Agriculture provided technical assistance in the field and provided copies of published and unpublished maps of soil surveys in Chambers and Jefferson Counties.

Marcus E. Milling, Marcus W. Walsh, Ben Wicker, and George Zahar, geology students at Lamar Tech, aided the author in mapping geomorphic features, in the preparation of illustrations, and in the determination of stream gradients.

General Stratigraphy and Structure

The geologic units in Chambers and Jefferson Counties (Figure 20) crop out in belts that are nearly parallel to the shoreline of the Gulf of Mexico. The beds dip toward the Gulf, with the older beds dipping at steeper angles than the younger beds. Most formations thicken downdip. The regional (gulfward) dip is interrupted by uplifts associated with salt domes and by arcuate belts of normal faults that are generally downthrown to the Gulf.

The oldest unit that crops out in Chambers and Jefferson Counties is the Beaumont Clay of Pleistocene age (Bernard, LeBlanc, and Major, 1962). The alluvial terrace deposits along the modern floodplains of the Trinity and Neches Rivers, mapped by Bernard (1950) as the "Deweyville beds", are probably of late Pleistocene and Holocene age. The youngest sediments are floodplain, deltaic, coastal marsh, mud flat, and beach (chenier) deposits of Holocene age.

Beaumont Clay

The Beaumont Clay crops out across most of Chambers and Jefferson Counties (Figure 20). The formation was described by Hayes and Kennedy (1903, p. 27-29), from exposures and from samples from wells in the vicinity of Beaumont, as a "series of yellow, gray, blue, brown, and black clays with black sands" overlying the "Columbia sands."

No definite type section has been described, and probably no complete section can be described from the outcrops alone. A type well or a combination type well and surface section can be established only when some unequivocal means of determining the base of the formation can be agreed upon. Bernard (1950) mapped the Beaumont in Texas as its presumed equivalent in Louisiana, the Prairie Formation; Doering (1956) mapped it as the Oberlin and Eunice Formations; Price (1947) mapped it as the Montgomery and Prairie Formations; and Bernard and LeBlanc (1965) reverted to the original name, Beaumont Clay, as used on the geologic map of Texas (Darton and others, 1937).

Two mappable facies of the Beaumont Clay occur in Chambers and Jefferson Counties: (1) a clayey facies composed of alluvial, deltaic, coastal marsh, and lagoonal deposits of clay, silty clay, and sandy clay; and (2) a sandy facies composed of barrier island and beach deposits of very fine to fine sand, which are of local importance as sources of small quantities of fresh ground water.

The clayey facies of the Beaumont composes almost all of the exposed Pleistocene sediments in Chambers and Jefferson Counties. For descriptions of these facies see Crout and others (1965), McEwen (1963, p. 63-64), Kunze and others (1963), and Graf (1966, p. 6, and Figure 8).

The sandy facies of the Beaumont Clay compose a very small percentage of the exposed Pleistocene sediments in Chambers and Jefferson Counties. The material is mostly very fine to fine, well-sorted sand of the barrier island and beach deposits (mapped separately on Figure 20). Grain-size determinations by mechanical analyses and heavy-mineral data are given in Graf (1966).

Deltaic and Meander Belt Deposits

Barton (1930a, 1930b) concluded that the coastal area of southeastern Texas was deltaic plain deposited by Pleistocene streams. The main evidence for this interpretation was the meandering pattern of the sandier soils, found in many places on the crests of low "levee" ridges. Barton pointed out that most of the present drainage is between and is controlled by the old levee or distributary ridges.

The major difference between the views of Barton and those of the author is in the significance of the levee or distributary ridges. Barton believed that the meander belts were a relict group of passes with a "palmate" pattern, similar to that of the present-day Mississippi Delta. The deposits of the Pleistocene Trinity River would therefore represent a delta as large as or larger than the present Mississippi Delta. Barton concluded that the Pleistocene Trinity River had a greater discharge and load than at present because of higher precipitation and a diminution in the drainage basin since the Pleistocene. The author believes that this group of passes was actually a succession of meander belts that terminated in relatively small deltas, similar in size to the present day Trinity River Delta.

A map compiled from the latest soil survey of Jefferson County (Crout and others, 1965) that shows the meander belts defined by mapping the soils that are related to fluviatile deposits is shown as Figure 21.

As shown in Figure 22, there are four well-preserved, more or less continuous meander belts and one less definite belt in Chambers and Jefferson Counties. In order of decreasing age, they are: (1) the Neches Ridge System, which roughly parallels the Neches River in the extreme eastern part of Jefferson

County—the relict meanders in this system are fragmentary and obscure, but the soils are similar to the soils found in the other systems;(2) the Barbers Hill System, between the Trinity River and Cedar Bayou; (3) the Sea Breeze System, in eastern Chambers County; (4) the Big Hill Ridge System; and (5) the China Ridge System, which is the best preserved and has the greatest continuity.

The system of straight stretches of relict stream channels to the northwest and southeast of the Smith Point and Pine Island barriers may be the remains of a stream that was not a tributary to the Pleistocene Trinity River but flowed directly into the Gulf. Figure 20 shows a number of anomalous meanders that cannot be defined as a coherent system.

The bluffs along Trinity Bay and along the valleys of the Trinity and Neches Rivers are the result of stream cutting during a glacial lowering of sea level. Wave erosion of the areas bordering Lake Anahuac and Trinity Bay has maintained the steepness of the bluffs in those areas. East of the Trinity River, the contact of the Deweyville deposits with the Beaumont Clay is marked by low scarps less than 10 feet in height.

The contact of the Beaumont Clay with the marsh and fluviatile deposits of Holocene age between Smith Point in Chambers County and Sabine Lake in Jefferson County has a digitate pattern, and only a few of the recesses are occupied by larger streams. Most of the salients of the Beaumont Clay are levee or distributary ridges similar to those of the Trinity River Delta, and the center lines of some of them are water-filled or marshy depressions. Those that do not have axial depressions can be identified by their sandy soils, by their terminal position in relation to the meander system, and by their areal pattern. The margins of most of these small deltas, which are about 5 feet above sea level, slope gently under the marsh deposits. The termination of the Neches Ridge System does not have a clearly digitate pattern, but does have approximately the same elevation as the other terminations.

The average slope of the surface of the Beaumont Clay east of the Trinity River in Chambers County is about 1 foot per mile. West of the Trinity River, the slope is about 1.5 feet per mile. The gradients of the two best preserved meander belts (not the old stream gradients) are: Big Hill Ridge System, 1.64 feet per mile; and China Ridge System, 0.92 foot per mile. The reconstructed stream gradients are: Big Hill Ridge System, 0.75 foot per mile; and China Ridge System, 0.49 foot per mile.

McEwen (1963), in his study of the most recent delta of the Trinity River, found that the whole delta was only about 15 feet thick. On this basis, a local thickness for the Beaumont Clay of less than 100 feet can easily be conjectured. Should a widespread and easily identifiable lithologic change be found that has some reasonable relationship to the subsurface projection of the surface of the Montgomery Formation, then perhaps the base of the Beaumont can be defined.

Barrier Island and Beach Deposits

The barrier island and beach deposits (Figure 20) were first described by W. A. Price (1933, 1947), and named for the occurrence at Ingleside, near Aransas Pass, Texas. As mapped by Price, the Ingleside System is a series of discontinuous features extending along most of the Gulf Coast of Texas. In Chambers and Jefferson Counties, the barrier island and beach deposits, which are composed of very fine to fine sand, may be divided into three sections—one in Chambers County and two in Jefferson County (see areas marked Qbb on Figure 20). The section in Chambers County consists mainly of three elongated parts, each less than 1 mile wide, extending from Smith Point northeastwardly for a distance of about 20 miles. the part from Smith Point to Lake Stephenson is a ridge that rises about 10 feet above the adjacent marshland (altitude about 12 feet). The ridge contains a number of small, nearly circular lakes. The remainder of this section is more easily identified on soil maps and aerial photographs. The sections in Jefferson County are west of Fannett and in the western part of the city of Beaumont. The one west of Fannett is an irregularly shaped area about 4 miles in width that is essentially a series of abandoned beaches of "cheniers" similar to those near Sabine Pass. Altitudes range from about 15 to 25 feet. This section is forested and is locally called "Lawhorn Woods." The section in the western part of the city of Beaumont is about 3 miles long and about 1 mile in width. The altitude is about 20 feet, but because of urban development, this section is difficult to identify.

Mounds and Depressions

Widespread surface features of the Beaumont Clay, and of the Deweyville deposits, are the "pimple mounds." These circular to elliptical mounds are about 15 to about 50 feet in diameter and 1 to 4 feet in height. They are almost exclusively limited to the sandier and siltier soils that underlie the relict meander belts and the barrier island and beach system. They are largely absent from the gentle swales or relict backswamp areas between meander belts and from some, but not all, of the relict lagoonal areas landward of the old barriers. Pimple mounds are best developed and most abundant on the old barriers.

The origin of pimple mounds is not clearly understood, and they have been considered the result of both organic and inorganic processes. Mounds of this type are not restricted to the Gulf Coast, and similar features elsewhere are sometimes referred to as mima mounds. Discussion of these features goes back to the 1870's; reviews of the literature and references can be found in Melton (1954), Holland and others (1952), and in Bernard and Leblanc (1965, p. 174-176).

The hog wallows or "gilgai microrelief" (Crout and others, 1965, p. 6; Mowery and others, 1960, p. 11, 33), are a minor but locally conspicuous kind of surface feature. These are areas of uneven or "wavy" ground consisting of very low mounds or microknolls (less than 2 feet in diameter and less than 8 inches in height) and intervening depressions. They usually become apparent after a heavy rain when the depressions impede surface drainage. In Chambers and Jefferson Counties, hog wallows are restricted to the clayier soils. They are thought to result from the unequal absorption of water or dehydration by certain clay minerals.

Geologic Age

The Beaumont Clay is at least 30,000 years old as determined by radiocarbon dating. McFarlan (1961, p. 133) reported that samples from the Prairie Formation of Louisiana (correlative with the Beaumont Clay) were "dead" and older than 30,000 years. Oyster shells collected by the author from the relict lagoonal area north of Lake Charles, Louisiana, were likewise "dead" and were older than 40,000 years according to Dr. E. L. Martin, Shell Development Co., Exploration and Production Research Division, Houston, Texas. The shell material collected near Winnie by Professor W. H. Matthews was also "dead" and older than 37,000 years according to the Humble Oil and Refining Company (now Esso Production Research), Houston, Texas.

Deweyville Deposits of Bernard (1950)

The Deweyville deposits in Chambers and Jefferson Counties are found along the Trinity and Neches Rivers and are intermediate between the Beaumont Clay and the modern flood plain deposits of the two rivers.

These deposits were first mapped and described by H. A. Bernard (1950), in an unpublished doctoral dissertation. They were named for the community of Deweyville, in Newton County, Texas, about 12 miles north of Orange, Texas, where the deposits form a terrace flanking the Holocene flood plain of the Sabine River. On the Beaumont and Houston Sheets of the Geologic Atlas of Texas (Bureau of Economic Geology, 1968a and 1968b), the Deweyville deposits are identified as the Deweyville Formation.

Along the Neches River in Jefferson County, the Deweyville deposits form a single-level terrace north of the city of Beaumont. The deposits range from silty clay to very fine sand in some places and from very fine sand to coarse sand in others. The top of these deposits, which are at least 30 feet thick, is about 20 feet above sea level.

In Chambers County, the Deweyville deposits are on the eastern side of the Trinity River where they form at least three terrace levels ranging in altitude from 15 to 25 feet. As seen in road cuts, the deposits are clayey silts and silty sands. In several sand pits, the clayey silts and silty sands are underlain by very fine to coarse sand. Incomplete soil maps in the office of the U.S. Soil Conservation Service in Anahuac show that the higher terraces are underlain in many places by soils that are characteristic of the Beaumont Clay, and therefore may be considerably older than the deposits along the Neches River where a sequence of terraces is not present.

The age of the Deweyville deposits has been determined by radiocarbon methods for several localities outside of Chambers and Jefferson Counties. Aronow (1967) reported on samples from deposits along the Trinity, San Jacinto, and Sabine Rivers; and B. H. Slaughter (1965) reported on a sample, which the author interprets to be Deweyville, from deposits along the Trinity River. The dates of these samples range from 13,250 to 25,700 years. Bernard and Leblanc (1965, p. 149) give dates ranging from 17,000 to 30,000 years, but no localities are identified in their paper.

Holocene Deposits

Alluvial and Deltaic Deposits

The principal alluvial deposits of Holocene age are along the Neches River in Jefferson County, along the Trinity River in Chambers County, and in an extensive area along the coast. The principal deltaic deposits of Holocene age are at the mouth of the Trinity River. A map by Kane (1959) showing subsurface contours on top of the oxidized Pleistocene deposits (base of the Holocene) in the vicinity of Sabine Lake is included on Figure 23.

The geomorphology of the floodplains and deltas of the Holocene Trinity River has been worked out in some detail by Aten (1966a and 1966b), who distinguishes a sequence of five delta terminations. The sediments and the three-dimensional geometry of the most recent delta have been studied in detail by McEwen (1963), who divides the sediments of the delta into nine facies or genetic groups.

The modern delta of the Trinity began to form within the past 1,000 years. McEwen (1963, p. 93) reports that the two oldest radiocarbon dates of articulated *Rangia flexuosa* shells found in cores taken near the bottom of delta-front churned sands in the northwest part of the delta are 810 years and 750 years old.

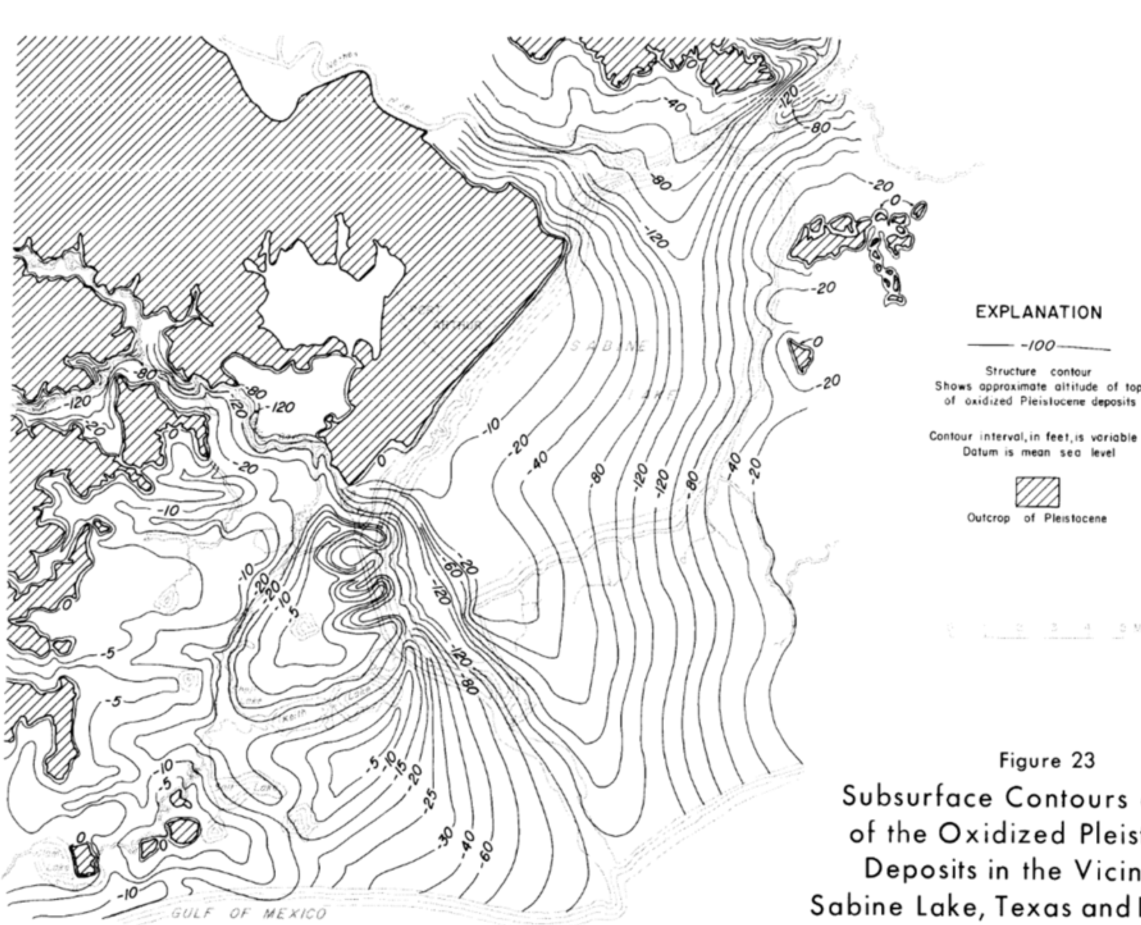

Figure 23
Subsurface Contours on Top of the Oxidized Pleistocene Deposits in the Vicinity of Sabine Lake, Texas and Louisiana

(From Kane, 1959)

Coastal Marsh, Mudflat, and Beach (Chenier) Deposits

The coastal marsh, mud flat, and beach (chenier) deposits along the southern margins of Chambers and Jefferson Counties are the most extensive of the Holocene deposits. The coastal marsh sediments underlie the low plains areas separated from the Gulf by the most recent beaches and include the deposits between relict beaches in the Sabine Pass area of Jefferson County (See Bernard and Leblanc, 1965, Figure 5). The mud flats are the areas of fine-grained sediments gulfward of the most recent beaches.

The surface features in the Sabine Pass area of Texas consist of low beach ridges and intervening relict mud flat or coastal marsh deposits. As can be seen on Figure 20, these arcuate beach ridges or cheniers, convex towards the present shoreline, merge to the southwest into a single beach along the present coast. The ridges, which are 3 to 8 feet in height and as much as 10 miles long, consist of very fine to fine sand with a highly variable shell content. The sand is similar in size to the Holocene beach sands of Galveston Island and Bolivar Peninsula to the west and to the cheniers in Louisiana to the east. (See Hsu, 1960, p. 381-384; Garner, 1967, p. 49-52, 57).

A number of wells, all less than 15 feet deep, have been developed in the beach and associated shell deposits.

Arcuate, fan-like arrangement of the beach ridges on the Texas side of Sabine Pass is more or less duplicated on the Louisiana side of the Pass. This arrangement undoubtedly indicates the gradual closing of the mouth of Sabine Lake by constriction of its southern connection with the Gulf. Originally, Sabine Lake must have been an open estuary of the Gulf. Kane (1959) in his study of the micro-fauna and sediments of Sabine Lake concludes that the micro-fauna, especially the foraminifers, found in the sediments beneath the lake "are similar to those of the present Gulf, indicating greater circulation of saline waters from the Gulf of Mexico before the south end of Sabine Lake was restricted".

Geologic History

The geologic history of the surface formations of Chambers and Jefferson Counties can be tied into the framework of the Pleistocene and Holocene history of the western Gulf Coast region as worked out by H. N. Fisk and his many associates. Later work and areal extensions of Fisk's concepts have been recently and excellently summarized in Bernard and LeBlanc (1965) which contains references to Fisk's many papers.

Fisk believed that the Pleistocene formations of Louisiana and Texas were all deposited as coast-wise terraces between the major stages of continental glaciations, with each successive Pleistocene formation being tilted gulfward. The amount of tilt was cumulative, so that the oldest formation has a considerably greater dip than the youngest.

The Montgomery Formation (with a regional slope of more than twice that of the Beaumont Clay) was deposited during the Sangamon Interglaciation; the Beaumont Clay, or Prairie Formation, was deposited during post-Sangamonian time. (See Fisk and McFarlan, 1955). The glacial stages were times of low sea level when the streams of the Gulf Coast entrenched their channels well below present-day sea level. Estimates of the lowering of sea level during the last glacial stage range from about 300 to 450 feet. The Trinity and Neches Rivers, during the last lowering of sea level, flowed over a 100-mile stretch of the then exposed continental shelf before discharging into the Gulf. (See maps in: Fisk and McFarlan, 1955, figure 4; Curray, 1965, figure 19a; Kane, 1959, figure 2). Kane's map of the oxidized zone at the top of the Beaumont Clay showed that the entrenched valleys of the Neches and Sabine Rivers joined under the present site of Sabine Lake (Figure 23). The sediments deposited since the beginning of the Holocene are those that lie above this marker horizon, which extends beneath the land areas and continues as an unconformity beneath the continental shelf. (See Bernard and LeBlanc, 1965, p. 150, 177-179; Curray, 1965, p. 733).

The time of the lowest sea level during the mid-Wisconsin has been estimated as more than 25,000 years ago by Bernard and LeBlanc (1965, p. 149) and about 18,000 years ago by Curray (1965, p. 723-724).

Sea level rose to its present level perhaps 3,000 to 5,000 years ago and has remained at about the same level. The various coastal features of Holocene age, seaward of the outcrop of the Beaumont Clay, are all less than 5,000 years old. Trinity Bay and Sabine Lake are essentially drowned valleys of the entrenched Pleistocene Trinity and Neches Rivers.

A few recent concepts and reformulations of the glacial stratigraphy and history of the midwestern United States have pointed up some areas where Fisk's theories seem to need revision; see Flint (1963), Frye and Willman (1960), Frye, Willman, and Black (1965), Frye and Leonard (1965), Curray (1965), Frye and Leonard (1953), Bernard and LeBlanc (1965), Durham (1965), Aten (1966a, 1966b), and Aronow (1967).

The Pleistocene history of the western Gulf Coast in general and of Chambers and Jefferson Counties in particular is far from worked out in detail, and much work remains to be done.

CONCLUSIONS AND RECOMMENDATIONS

Only small supplies of fresh ground water exist in the aquifers in Chambers and Jefferson Counties. Most of the fresh water used is surface water from the Trinity and Neches Rivers. Fifty-two percent of the ground water used is imported from neighboring counties. Large quantities of fresh ground water are available in adjoining counties and any large-scale demand for fresh ground water will likely be met by additional importation. Except for Beaumont's planned expansion of its well field in Hardin County, most future water needs will probably be met by surface-water supplies. Additional small fresh water supplies can be developed in Chambers and Jefferson Counties, but this development should be preceded by a careful program of testing and evaluation.

To fully utilize available ground water, the observation-well program in Chambers and Jefferson Counties to obtain data on both quality of water and water levels should not only be continued, but expanded and combined with the programs in adjacent counties. At present, the observation-well program in Chambers and Jefferson Counties covers only parts of the area. The expansion of this program should consider the planned increase of pumpage in Hardin County as well as anticipated increases in other counties. New wells should be continually inventoried, and aquifer tests should be made on the new wells to obtain additional information on the hydraulic properties of the aquifers. Collection of water samples should be expanded to monitor salt movement in all areas. Detailed observation of water levels and water quality in the vicinity of the salt domes, particularly in the vicinity of Mont Belvieu, is needed in order to more precisely define and predict the movement of water in these areas of salinization.

Subsidence, as related to ground-water production, is, and will likely remain, a minor problem because additional development will probably be limited. Water levels will probably continue to be lowered by pumping in adjacent counties. However, data derived from measurements of subsidence when used with geologic and hydrologic data are useful in determining maximum water availability. This type of data has been used in the construction of analog models in this area. Also, knowledge of amount and rate of subsidence is important in planning surface drainage and water transfer facilities. Thus, an expanded program for measuring subsidence is needed in Chambers and Jefferson Counties. Further delay in starting such a program may prevent accurate determination of total subsidence and rates of subsidence. An enlarged network of bench marks should be established and leveled periodically. This program should be in conjunction with the program for the collection of water-level and pumpage records, so that correlations of cause and effect of subsidence can be made in the future.

Electrical-analog models are useful in the evaluation of aquifers. Such a model has been completed for the aquifers of the Houston district (Wood and Gabrysch, 1965). A preliminary model of the Chicot and Evangeline aquifers in southeast Texas and southwest Louisiana, including Chambers and Jefferson Counties, has been constructed. The program recommended above will provide data that could be used to improve the models and aid in the proper planning and development of the ground-water resources of Chambers and Jefferson Counties.

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Table 5.—Drillers' Logs of Wells in Chambers and Jefferson Counties

Chambers County

Well DH-64-04-709

Owner: Gulf Oil Co.
Driller: Gulf Oil Co.

	THICKNESS (FEET)	DEPTH (FEET)
Clay, surface	15	15
Gumbo	37	52
Sand	58	110
Gumbo	18	128
Sand	21	149
Gumbo	25	174
Sand	22	196
Gumbo	2	198

Well DH-64-09-301

Owner: Chambers County Water Control & Improvement District No. 1 Well 5
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Soil	4	4
Clay	111	115
Clay, sandy	45	160
Shale	30	190
Shale, sandy and shale	100	290
Shale	108	398
Sand, fine gray	72	470
Shale	4	474
Sand, coarse white	46	520
Shale	10	530

Well DH-64-09-302

Owner: Chambers County Water Control & Improvement District No. 1 Well 4
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Soil	4	4
Clay	112	116
Shale, sandy	42	158
Shale	175	333
Sand and shale	8	341
Shale and streaks of sand	60	401
Sand, gray	74	475
Shale	3	478
Sand, coarse white	43	521
Shale	20	541
Sand	13	554
Shale and streaks of sand	34	588
Sand	8	596
Shale and sandy shale	51	647
Sand	21	668
Shale	16	684
Sand and streaks of shale	40	722
Shale	5	727
Sand, coarse and streaks of shale	65	792
Shale and streaks of sand	16	808
Sand and streaks of shale	29	837
Shale	10	847
Sand	13	860
Shale	18	878
Shale and sand streaks	26	904
Sand, fine and shale streaks	101	1,005
Shale and sand streaks	63	1,068
Sand	5	1,073
Shale and sandy shale	53	1,126
Sand, fine white	13	1,139
Shale, sandy and shale	15	1,154
Sand	13	1,167
Shale and sandy shale	83	1,250

Well DH-64-09-305

Owner: Diamond Alkali Co. Well 4
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	4	4
Clay	31	35
Clay and lime breaks	41	76
Clay, sandy and few lime breaks	40	116
Clay, sticky	20	136
Clay, sandy	14	150
Clay	55	205
Sand	18	223
Clay	47	270
Clay, sandy	27	297
Sand and clay breaks	40	337
Shale, sandy	14	351
Sand, broken	19	370

Table 5.—Drillers' Logs of Wells in Chambers and Jefferson Counties—Continued

Well DH-64-09-305—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Shale	21	391
Shale, sandy	17	408
Shale	20	428
Sand	32	460
Sand, broken	25	485
Shale, sandy	24	509
Sand and shale breaks	19	528
Sand	37	565
Sand and shale streaks	29	594
Rock	1	595
Shale	28	623
Shale, sandy and sand	21	644
Shale	32	676
Shale, sandy	11	687
Sand	18	705
Shale	14	719
Sand	51	770
Sand and shale streaks	18	788
Sand and few shale breaks	76	864
Shale	11	875
Sand and shale, broken	30	905
Sand	23	928
Shale, sandy and shale breaks	25	953
Shale	22	975
Shale, sandy	10	985
Sand and lime breaks	125	1,110
Sand and shale breaks	124	1,234
Shale	10	1,244
Sand	37	1,281
Shale	10	1,291
Sand	10	1,301
Shale	37	1,338
Sand	19	1,357
Shale, sandy	5	1,362
Sand and shale breaks	44	1,406
Shale	11	1,417

Well DH-64-09-306

Owner: Warren Petroleum Co.
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	10	10
Clay	113	123
Sand	15	138
Shale	172	310
Sand	60	370
Shale, sandy	70	440
Sand-cut good	90	530
Sand and layers of rock	5	535
Sandy coarse-cut good, little hard	43	578
Shale	112	690
Sand, coarse with hard shale breaks	96	786
Sand-cut good	37	823
Sand, coarse with hard shale breaks	94	917
Shale-few sand breaks	81	998
Sand, fine	33	1,031
Sand, fine with shale breaks	54	1,085
Sand	41	1,126
Shale and streaks of sand	25	1,151
Sand	30	1,181
Shale	9	1,190
Sand and streaks of shale	29	1,219
Shale	26	1,245
Sand	20	1,265
Shale and few sand breaks	21	1,286
Sand	27	1,313
Shale	40	1,353
Sand and few shale breaks	103	1,456
Shale	11	1,467
Sand, coarse, cut good	22	1,489
Shale	8	1,497
Sand, coarse and shale breaks	30	1,527
Shale	32	1,559
Sand, cut poorly	16	1,585
Shale	21	1,606
Shale, sandy	10	1,616
Shale	5	1,621
Shale, sandy	5	1,626

Well DH-64-09-307

Owner: Diamond Alkali Co. Well 3
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Clay	98	98
Sand	102	200
Clay, sandy	117	317
Sand	100	417
Sand and shale streaks	260	677
Shale	23	700
Sand	28	728
Sand and shale breaks	189	917
Shale and sand streaks	103	1,020
Sand and sandy shale	180	1,200

Well DH-64-09-310

Owner: Chambers County Water Control & Improvement District No. 1
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Soil	5	5
Clay	60	65
Sand, white, coarse	22	87
Clay	12	99
Sand layers and shale	17	116
Shale	8	124
Sand	12	136
Shale	20	156
Sand, gray, coarse	25	181
Sand, coarse, and traces of gravel	35	216
Shale	10	226

Well DH-64-09-314

Owner: Asa Wilburn
Driller: Amos Jennische

	THICKNESS (FEET)	DEPTH (FEET)
Soil	2	2
Clay	58	60
Shale and fine sand	9	69
Gumbo	21	90
Gumbo and shale	46	136
Sand	20	156

Well DH-64-09-315

Owner: Chambers County Water Control & Improvement District No. 1
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	5	5
Clay	47	52
Sand, brown, fine	9	61
Shale	14	75
Shale, sandy	30	105
Shale	84	189
Sand, white, fine	18	207
Sand and shale streaks	11	218
Shale	8	226
Sand, coarse	25	251
Shale	21	272
Sand, blue	11	283
Shale	6	289
Sand, white, coarse	51	340

Well DH-64-09-316

Owner: Sun Oil Co.
Driller: Sun Oil Co.

	THICKNESS (FEET)	DEPTH (FEET)
Clay and sand	99	99
Clay	12	111
Sand and boulders	42	153
Gumbo	184	337
Sand and gravel	95	432
Rock	2	434
Sandy shale	30	464
Sand	14	478
Gumbo	128	606
Sand	18	624
Gumbo	2	626

Well DH-64-09-318

Owner: Crumpler Brothers
Driller: Homer Wright

	THICKNESS (FEET)	DEPTH (FEET)
Soil and sandy clay	30	30
Sand	14	44
Clay	8	52
Clay, sandy	24	76

	THICKNESS (FEET)	DEPTH (FEET)
Well DH-64-09-318—Continued		
Sand	14	90
Gumbo	22	112
Sand	17	129
Gumbo	33	162
Sand	10	172
Gumbo	10	182
Sand	6	188
Gumbo	3	191
Sand, white, coarse	24	215
Sand, blue, fine, and wood	6	221
Gumbo, light blue	3	224
Sand, white, coarse	12	236
Shale, sticky	18	254
Well DH-64-09-319		
Owner: Crumpler Brothers Driller: Homer Wright		
Sand, soil and clay	76	76
Sand	14	90
Clay, sandy	93	183
Sand	7	190
Gumbo	4	194
Sand	44	238
Gumbo	10	248
Shale, sandy	34	282
Sand and boulders	58	340
Sand, shale and boulders	68	408
Gumbo	24	432
Shale, sandy	34	466
Sand	8	474
Gumbo	9	483
Sand, coarse	25	508
Gumbo	10	518
Sand, fine	52	570
Sand, coarse	30	600
Shale	3	603

	THICKNESS (FEET)	DEPTH (FEET)
Well DH-64-09-321		
Owner: Crumpler Brothers Driller: Homer Wright		
Soil and sand	20	20
Clay	20	40
Shale, sandy	138	178
Shale, hard	26	204
Sand, fine	33	237
Shale, green	4	241
Sand, fine	42	283
Sand, coarse	21	304
Well DH-64-09-324		
Owner: J. O. Stockbridge Driller: C. A. Williams		
Clay, yellow	64	64
Gumbo, tough	28	92
Shale, sandy	23	115
Sand, soft	30	145
Gumbo, soft and sand	27	172
Gumbo, tough	16	188
Gumbo, soft and sand	22	210
Gumbo, tough	10	220
Sand and shale	20	240
Gumbo, sticky	41	281
Sand and gumbo	5	286
Sand, hard	28	314
Well DH-64-09-327		
Owner: Crumpler Brothers Driller: Homer Wright		
Soil and clay	10	10
Sand	9	19
Clay	6	25
Sand	10	35
Sand and clay	25	60
Sand	16	76
Clay, hard	6	82
Sand	10	92
Gumbo	17	109
Sand	21	130

	THICKNESS (FEET)	DEPTH (FEET)
Well DH-64-09-327—Continued		
Gumbo	9	139
Sand	6	145
Gumbo	40	185
Shale, sandy	12	197
Sand	44	241
Gumbo and sand	40	281

Well DH-64-09-328

Owner: Tillman Fitzgerald
Driller: Amos Jennische

	THICKNESS (FEET)	DEPTH (FEET)
Soil	3	3
Clay	17	20
Shale	50	70
Gumbo	5	75
Shale and sand	10	85
Gumbo	15	100
Shale and gumbo	10	110
Gumbo	85	195
Shale	9	204
Sand, fine	3	207
Gumbo and shale	48	255
Gumbo	52	307
Shale and sand	10	317
Sand	83	400
Gumbo	93	493
Sand	17	510

Well DH-64-09-329

Owner: Temple Fitzgerald
Driller: Amos Jennische

	THICKNESS (FEET)	DEPTH (FEET)
Soil	3	3
Clay	3	6
Quicksand	29	35
Shale	25	60
Gumbo and shale	20	80
Gumbo	120	200
Shale	9	209
Sand	8	217

Well DH-64-09-613

Owner: Humble Oil & Refining Co.
Driller: Lowry Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Clay, yellow and white	72	72
Sand	41	113
Shale	13	126
Sand, good	14	140

Well DH-64-09-903

Owner: John Nelson
Driller: Katy Drilling Co.

	THICKNESS (FEET)	DEPTH (FEET)
Clay and topsoil	137	137
Sand and clay strips	48	185
Clay	63	248
Shale, sandy	22	270
Clay	50	320
Shale, sandy	20	340
Clay	37	377
Sand	30	407
Clay and sand strips	15	422
Sand, rocky and clay strips	71	493
Clay	27	520
Sand	6	526
Clay and sand strips	27	553
Sand and clay strips	44	597
Clay and sand strips	118	715
Sand	11	726
Clay	20	746
Sand and clay strips	85	831
Sand, fine	76	907
Clay	5	912
Sand and clay	33	945

Well DH-64-09-918

Owner: Houston Lighting & Power Co.
Driller: --

	THICKNESS (FEET)	DEPTH (FEET)
Clay, small sand breaks	70	70
Sand	31	101
Clay with small sand breaks	147	248
Clay and sandy clay	86	334
Sand and gravel with clay breaks	71	405

	THICKNESS (FEET)	DEPTH (FEET)
Well DH-64-09-918—Continued		
Sand	1	406
Clay	2	408
Sand	31	439
Clay	19	458
Sand with clay breaks	7	465
Sand	20	485
Sand and hard streaks	126	611
Sand, fine	20	631
Sandy clay with streaks of sand	15	646
Clay with sandy clay	31	677
Sand and clay	8	685
Clay, sandy clay, and streaks of sand	37	722
Sand, fine	15	737
Clay and streaks of sand	19	756
Sand and streaks of clay	52	808
Sand and sandy clay	50	858
Clay and sandy clay	113	971
Sand, fine	19	990
Clay	8	998
Sand	60	1,058
Sand and streaks of clay	19	1,077
Clay and sandy clay	11	1,088
Sand	5	1,093
Clay and sandy clay with streaks of sand	22	1,115
Sand and streaks of clay	25	1,140
Sand	7	1,147
Sandy clay with streaks of clay	29	1,176
Clay and sandy clay	21	1,197
Sand, fine	19	1,216
Clay and sandy clay	10	1,226
Sand	63	1,289
Clay	9	1,298
Clay	8	1,306
Sand	6	1,312
Sandy clay and hard streaks	9	1,321
Sand	22	1,343
Clay	3	1,346
Sand and hard streaks	25	1,371
Clay	4	1,375

Well DH-64-10-205

Owner: Will Icet
Driller: Amos Jennische

	THICKNESS (FEET)	DEPTH (FEET)
Soil	6	6
Clay	124	130
Sand	15	145
Gumbo, sand and shale	205	350
Gumbo	129	479
Sand	13	492

Well DH-64-10-206

Owner: H. C. Icet
Driller: C. A. Williams

	THICKNESS (FEET)	DEPTH (FEET)
Clay, red	150	150
Gumbo	20	170
Sand, fine	10	180
Gumbo	30	210
Sand	10	220
Gumbo, hard	60	280
Shale, soft	25	305
Sand, coarse	35	340
Sand, fine	30	370

Well DH-64-10-302

Owner: Mayes Estate
Driller: Texas Highway Dept.

	THICKNESS (FEET)	DEPTH (FEET)
Soil, black, sandy	3	3
Clay, gray, soft, sandy	4	7
Clay, yellow, sticky	2	9
Sand, yellow, water	14	23
Sand, water	8	31
Clay, brown and gray, sandy with small shells	8	39
Clay, brown and blue	2	41
Clay, brown and blue streaked	15	56
Clay, brown and blue streaked hard	2	58

	THICKNESS (FEET)	DEPTH (FEET)
Well DH-64-10-302—Continued		
Clay, hard, light-brown streaked	1	59
Clay, light-blue streaked	10	69
Clay, blue, sandy, soft	1	70
Sand, blue, water	8	78
Sand, blue, soft, water	8	86
Sand, blue, water	2	88
Clay, blue	1	89
Sand, blue, water	31	120
Clay, blue	7	127
Sand, blue, water	7	134
Clay, blue, soft, sandy	1	135
Sand, blue, water	13	148
Sand	15	346
Shale	8	354
Sand	8	362
Shale	68	430
Shale, sandy	10	440
Shale	30	470
Sand	18	488

Well DH-64-10-401

Owner: Finger Furniture Co.
Driller: Katy Drilling Co.

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil and clay	132	132
Sand and clay strips	58	190
Clay	45	235
Sand, real fine	12	247
Clay, blue	83	330
Sand	61	391
Clay	52	443
Sand, fine	63	506
Clay and sand strips	54	560
Clay	30	590
Sand	7	597
Clay and sand strip	68	665
Sand, rock, and clay strips	51	716
Clay and sand strips	39	755
Sand, rocky and clay	116	871

Well DH-64-10-405

Owner: C. O. Williams
Driller: Jim Avera

	THICKNESS (FEET)	DEPTH (FEET)
Sand	2	2
Clay	85	87
Sand, coarse	40	127
Shale	204	331

Well DH-64-10-406

Owner: Jack Rosenau
Driller: Jim Avera

	THICKNESS (FEET)	DEPTH (FEET)
Clay	118	118
Shale, sandy	10	128
Sand, water	21	149

Well DH-64-10-408

Owner: Ben Dutton
Driller: Amos Jennische

	THICKNESS (FEET)	DEPTH (FEET)
Soil	3	3
Clay	93	96
Shale	22	118
Sand	25	143

Well DH-64-10-501

Owner: C. T. Joseph, Jr.
Driller: Katy Drilling Co.

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil and clay	110	110
Sand	23	133
Clay	38	171
Sand	98	269
Clay	10	279
Sand	31	310
Clay	35	345
Sand, shale	22	367
Sand	20	387
Clay	28	415
Shale, soft	32	447
Sand and shell	19	466
Clay	13	479
Shale, soft	49	528

	THICKNESS (FEET)	DEPTH (FEET)
Well DH-64-10-501—Continued		
Shale, soft, and sandy strips	38	566
Shale and small clay strips	35	601
Sand	15	616
Shale	112	728
Sand, rocky	181	909
Shale	1	910
No record	2	912

Well DH-64-10-504

Owner: Ernest Winfree
Driller: Amos Jennische

	THICKNESS (FEET)	DEPTH (FEET)
Soil	3	3
Clay	112	115
Sand	6	121
Gumbo	6	127
Rock and boulders	8	135
Gumbo	50	185
Shale	19	204
Sand	18	222

Well DH-64-10-511

Owner: Hugh Welch
Driller: Jim Avera

	THICKNESS (FEET)	DEPTH (FEET)
Clay	94	94
Sand, water	24	118
Shale with sand streaks	42	160
Shale, sticky	110	270
Shale, sandy	8	278
Shale, sticky	62	340
Sand, water	26	366
Shale, sticky	39	405
Shale, sandy	7	412
Shale, sticky	63	475
Sand, water	26	501

Well DH-64-10-512

Owner: C. T. Joseph Estate
Driller: Amos Jennische

	THICKNESS (FEET)	DEPTH (FEET)
Clay	98	98
Sand	20	118
Gumbo and shale	147	265
Shale, sandy	10	275
Gumbo	70	345
Sand	15	360
Gumbo	120	480
Sand	28	508

Well DH-64-10-514

Owner: Mayes Estate
Driller: Texas Highway Dept.

	THICKNESS (FEET)	DEPTH (FEET)
Clay, brownish-yellow and shell	1	1
Clay, yellow, soft, brown	1	2
Clay, yellow	1	3
Clay, yellow and gray and some white gravel	1	4
Clay, yellow and gray	4	8
Clay, yellow and gray, sandy	1	9
Clay, yellow and gray	4	13
Clay, yellow and gray, sandy	1	14
Clay, yellow with white gravel	3	17
Clay, gray and yellow	4	21
Clay, yellowish-blue and gray	1	22
Clay, red, yellow and blue	3	25
Clay, red, yellow and blue, sandy, water	1	26
Clay, red and gray	5	31
Clay, yellow and blue	10	41
Clay, blue and brown	5	46

Well DH-64-10-516

Owner: C. T. Joseph Estate
Driller: Jim Avera

	THICKNESS (FEET)	DEPTH (FEET)
Soil	2	2
Clay	146	148
Sand	12	160
Shale	118	278
Sand	5	283
Shale	62	345
Sand	8	353
Shale	145	498
Sand	14	512

	THICKNESS (FEET)	DEPTH (FEET)
Well DH-64-10-702		
Owner: Texas Oil and Gas Co. Driller: Homer Wright		
Clay and sand	185	185
Sand	27	212
Shale and sand	105	317
Sand	25	342
Shale	58	400
Sand	75	475
Well DH-64-10-703		
Owner: V. A. Lawrence Driller: Pitre Water Wells		
Clay	71	71
Sand	3	74
Gravel	1	75
Clay	15	90
Clay, sandy	8	98
Gravel	2	100
Clay, sandy	14	114
Sand	7	121
Clay	4	125
Sand, fine	16	141
Clay	7	148
Sand, fine	7	155
Clay	19	174
Clay, fine sand with lens of clay	31	205
Clay	29	234
Clay with lens of sand and gravel	16	250
Sand	12	262
Clay	2	264
Sand, fine, water	4	268
Sand, coarse, water	10	278
Gravel, water	6	284
Sand, fine, water	6	290
Clay, blue	15	305
Sand	10	315
Clay, sandy	5	320
Sand and gravel	19	339
Clay	9	348
Gravel	2	350
Shale, sandy	12	362
Sand	4	366
Clay	18	384
Sand and gravel	1	385
Clay	2	387
Sand, fine	3	390
Clay, sandy	3	393
Clay	7	400
Sand and gravel, water	43	443
Well DH-64-10-707		
Owner: V. A. Lawrence Driller: Luther Patterson		
Surface	24	24
Shale	124	148
Sand	49	197
Shale	11	208
Sand	44	252
Shale	133	385
Sand, water	44	429
Well DH-64-10-801		
Owner: Amos Lawrence Estate Driller: Amos Jennische		
Soil	3	3
Shale	52	55
Sand	5	60
Shale	10	70
Gumbo, soft	65	135
Sand	10	145
Gumbo	60	205
Sand, fine	25	230
Gumbo, soft	43	273
Gumbo and rock	2	275
Sand	25	300
Gumbo	65	365
Sand	34	399

Well DH-64-11-105

Owner: A. H. Stade
Driller: B & L Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Clay	9	9
Sand	25	34
Shale	76	110
Sand	20	130
Shale	33	163
Sand	15	178

Well DH-64-11-205

Owner: Stanolind Oil and Gas Co.
Driller: Pitre Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Clay	31	31
Sand, water	17	48
Clay, tough	19	67
Sand, fine	34	101
Clay	9	110
Sand, water	26	136
Shale	23	159
Sand	3	162
Shale	7	169
Sand, water	6	175
Clay, tough	23	198
Sand	3	201
Shale	12	213
Shale, sandy	7	220
Sand	1	221
Shale, sandy	6	227

Well DH-64-11-206

Owner: Stanolind Oil and Gas Co.
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Clay	11	11
Sand	43	54
Clay	29	83
Sand	23	106
Clay	11	117
Sand	19	136
Clay	4	140

Well DH-64-11-401

Owner: E. S. Abshier
Driller: Katy Drilling Co.

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	5	5
Sand	25	30
Clay	82	112
Sand	30	142
Clay	65	207
Sand	12	219
Clay	10	229
Sand	40	269
Clay	71	340
Sand	42	382
Clay	110	492
Sand, rocky	38	530
Clay	10	540
Sand, rocky	27	567
Clay	11	578
Sand and clay	17	595

Well DH-64-11-502

Owner: Sun Oil Co.
Driller: Sun Oil Co.

	THICKNESS (FEET)	DEPTH (FEET)
Sand, surface and clay	108	108
Shale, gravel and sand	88	196
Shale and gravel	420	616
Shale	100	716
Shale and sand	244	960
Sand and gravel	130	1,090
Shale and sand	162	1,252

Well DH-64-11-802

Owner: City of Anahuac Well 1
Driller: Big State Drilling Co.

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	2	2
Clay	3	5
Clay and sand	15	20
Clay	10	30
Shale	40	70
Clay	10	80

Table 5.—Drillers' Logs of Wells in Chambers and Jefferson Counties—Continued

Well DH-64-11-802—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Sand, water	40	120
Clay, sandy	10	130
Shale	20	150
Shale, sandy	48	198
Clay	2	200
Sand	5	205
Shale, sandy	120	325
Sand, poor	25	350
Shale	10	360
Sand and shale, layers	60	420
Shale	20	440
Sand, poor	20	460
Sand and shale broken layers	59	519

Well DH-64-11-911

Owner: L. F. Fancher
Driller: Pitre Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Clay, vari-colors	97	97
Sand, fine, white	25	122
Sand and clay, broken	3	125

Well DH-64-11-914

Owner: W. H. Otken
Driller: Andy Frankland

	THICKNESS (FEET)	DEPTH (FEET)
Surface sand	2	2
Clay, yellow	158	160
Sand, fine	15	175
Gumbo, gray	145	320
Sand	20	340

Well DH-64-12-107

Owner: M. P. Hatley
Driller: Andy Frankland

	THICKNESS (FEET)	DEPTH (FEET)
Surface sand	2	2
Clay, yellow	60	62
Sand	29	91

Well DH-64-12-109

Owner: Roy E. Abshier
Driller: Pitre Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Clay	22	22
Sand, very fine, white	16	38

Well DH-64-12-204

Owner: C. A. Fowler
Driller: J. E. Abshier

	THICKNESS (FEET)	DEPTH (FEET)
Soil	4	4
Clay	8	12
Sand	22	34

Well DH-64-12-206

Owner: C. J. Musgrove
Driller: Andy Frankland

	THICKNESS (FEET)	DEPTH (FEET)
Surface sand	2	2
Clay, yellow	52	54
Sand, fine	26	80
Gumbo	185	265
Sand	15	280
Gumbo	11	291
Sand	19	310

Well DH-64-12-303

Owner: W. E. Jenkins
Driller: Pitre Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Clay, tough, yellow	194	194
Sand, fine, gray	10	204
Shale, blue	74	278
Sand, fine, gray	10	288
Shale, blue	32	320
Sand, fine, gray	5	325
Shale, gray	20	345
Sand, fine, gray	5	350
Sand, loose, gray	23	373
Shale, medium	25	398
Sand, soft, dark-gray, very fine	5	403

Well DH-64-12-502

Owner: Humble Oil and Refining Co.
Driller: Humble Oil and Refining Co.

	THICKNESS (FEET)	DEPTH (FEET)
Clay	91	91
Sand and gravel	4	95
Clay	35	130
Sand, water	17	147

Well DH-64-12-704

Owner: Humble Oil and Refining Co.
Driller: L. Patterson

	THICKNESS (FEET)	DEPTH (FEET)
Clay	22	22
Sand	25	47
Clay	4	51
Sand	8	59
Clay	4	63

Well DH-64-13-102

Owner: Sun Oil Co.
Driller: A-1 Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Soil, black surface	4	4
Clay, yellow	18	22
Sand, yellow	3	25
Shale, yellow	25	50
Sand, fine, blue	6	56
Shale, sticky	42	98
Sand, fine, gray	27	125
Shale, soft, blue	15	140
Sand, gray, water	35	175

Well DH-64-13-106

Owner: Lawrence Rowland
Driller: V. R. Phelps

	THICKNESS (FEET)	DEPTH (FEET)
Clay	40	40
Shell, oyster	20	60
Clay	46	106
Sand	74	180

Well DH-64-13-112

Owner: C. B. Jeffery
Driller: Andy Frankland

	THICKNESS (FEET)	DEPTH (FEET)
Surface sand	2	2
Clay, yellow	103	105
Sand, and clay, fine	15	120
Clay, gray	39	159
Sand	17	176

Well DH-64-13-601

Owner: Trinity Bay Conservation District Well 1
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	3	3
Clay	114	117
Sand, coarse	28	145
Clay	46	191
Sand, fine, gray	21	212
Clay	49	261

Well DH-64-13-602

Owner: Trinity Bay Conservation District Well 2
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Clay	115	115
Sand, white	33	148
Clay	41	189
Sand, gray	20	209
Clay	52	261

Well DH-64-13-604

Owner: H. M. Franssen
Driller: V. R. Phelps

	THICKNESS (FEET)	DEPTH (FEET)
Clay	20	20
Sand, blue, fine	80	100
Clay	40	140
Sand	22	162

Well DH-64-13-616

Owner: Sinclair Refining Co.
Driller: Lowry Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Surface, clay	18	18
Sand, gray	46	64
Shale, blue	61	125
Sand, good	25	150
Shale, soft	2	152

Well DH-64-13-617

Owner: Wilson LeBlanc
Driller: Green Bros. Water Well Service

	THICKNESS (FEET)	DEPTH (FEET)
Clay, yellow	16	16
Sand, white	34	50

	THICKNESS (FEET)	DEPTH (FEET)
Well DH-64-14-102		
Owner: S. J. Ryan Driller: Pitre Water Wells		
Clay, medium	20	20
Sand, fine	29	49
Clay, medium	64	113
Sand, coarse	35	148
Clay, medium	8	156
Sand, soft	20	176
Clay, medium	22	198
Well DH-64-14-704		
Owner: J. B. Myers Driller: V. R. Phelps		
Clay	35	35
Quicksand	4	39
Clay	150	189
Sand	8	197
Well DH-64-17-212		
Owner: C. Vickers Driller: Amos Jennische		
Clay	74	74
Sand	29	103
Shale	37	140
Shale and gumbo	60	200
Gumbo	125	325
Sand, fine and shale	10	335
Sand	11	346
Well DH-64-17-302		
Owner: The Texas Co. Driller: Pitre Water Wells		
Clay, red	71	71
Sand	28	99
Shale, blue	8	107
Sand, hard	13	120
Shale, blue	92	212
Sand, hard	47	259
Shale, blue	61	320
Sand, hard	7	327
Shale	5	332
Sand	66	398
Well DH-64-17-304		
Owner: The Texas Co. Driller: Pitre Water Wells		
Clay, medium	64	64
Sand, soft	44	108
Shale, blue and shell	75	183
Sand, white fine	37	220
Shale with coarse sand	178	398
Shale, hard	120	518
Sand, hard	47	565
No record	19	584
Well DH-64-17-305		
Owner: The Texas Co. Driller: Pitre Water Wells		
Clay, medium red	40	40
Shale, medium blue	25	65
Shale, medium blue and sand	15	80
Sand, rough, white and gravel	28	108
Shale, blue, sticky	36	144
Sand, medium fine, blue and shale	31	175
Shale, medium blue, sandy	44	219
Shale, medium blue	32	251
Sand, medium white, rough, fine	22	273
Sand, soft, white, fine	22	295
Clay, sticky, blue	49	344
Sand, rough, white	28	372
Well DH-64-17-307		
Owner: Odell Fisher Driller: Amos Jennische		
Soil	3	3
Clay	77	80
Sand	16	96

	THICKNESS (FEET)	DEPTH (FEET)
Well DH-64-17-308		
Owner: B. D. Fisher Driller: Amos Jennische		
Soil	3	3
Clay	77	80
Sand	17	97
Well DH-64-17-601		
Owner: Asa Wilburn Driller: Amos Jennische		
Soil	3	3
Clay	71	74
Sand	20	94
Well DH-64-17-607		
Owner: J. C. Fowler Driller: Amos Jennische		
Soil	3	3
Clay	12	15
Quicksand	5	20
Clay	10	30
Quicksand	15	45
Clay	50	95
Sand	10	105
Well DH-64-17-610		
Owner: Jones & Laughlin Steel Co. Driller: Layne-Texas Co.		
Clay	75	75
Clay, sandy	16	91
Sand, broken	29	120
Shale	30	150
Sand and shale layers	35	185
Shale and sandy	46	231
Sand, broken and shale	10	241
Shale	146	387
Shale, sandy	8	395
Shale	38	433
Sand and shale streaks	9	442
Shale	50	492
Sand and shale streaks	93	585
Shale	5	590
Sand	5	595
Shale	26	621
Sand, broken and shale layers	14	635
Shale and sandy shale	58	693
Shale	18	711
Sand, broken	20	731
Shale	28	759
Sand	80	839
Shale	6	845
Sand-fine and shale breaks	30	875
Shale, hard	32	907
Sand	5	912
Shale, sandy	12	924
Sand	6	930
Shale, hard	20	950
Sand, fine	35	985
Shale	8	993
Sand	25	1,018
Shale	8	1,026
Sand	6	1,032
Shale, sandy	9	1,041
Sand and shale streaks	80	1,121
Shale	17	1,138
Sand and shale streaks	52	1,190
Shale, hard	29	1,219
Sand and shale streaks	39	1,258
Shale	48	1,306
Sand	26	1,332
Shale	8	1,340
Sand	58	1,398
Shale	4	1,402
Sand	32	1,434
Shale and sandy shale	7	1,441
Sand and shale streaks	54	1,495
Shale and sandy shale	18	1,513

Well DH-64-17-901

Owner: Seacrest Park
Driller: Pitre Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Sand	18	18
Clay	7	25
Sand	25	50
Shale	17	67
Sand	63	130
Clay	8	138
Sand and shale	12	150
Sand, soft, green, and shale	80	230
Clay, medium red	13	243
Sand, soft gray	8	251
Shale, medium blue	43	294
Shale, soft green	36	330
Shale, hard blue, boulders	53	383
Shale, soft gray	11	394
Gumbo, medium blue	42	436
Shale, medium green and sand	15	451
Shale, medium shale and sand	13	464
Shale, medium blue	28	492
Sand, soft gray	43	535
Shale, medium blue	19	554
Sand, soft gray	63	617
Clay, red medium	15	632
Sand, fine, soft gray, water	68	700
Shale, medium blue	3	703
No Record	6	709

Well DH-64-18-104

Owner: E. E. Barrow
Driller: Luther Patterson

	THICKNESS (FEET)	DEPTH (FEET)
Surface	24	24
Shale	197	221
Sand	22	243
Shale	43	286
Sand	54	340

Well DH-64-18-107

Owner: Irvin Bishop
Driller: Amos Jennische

	THICKNESS (FEET)	DEPTH (FEET)
Soil	3	3
Clay	122	125
Sand and shale	5	130
Gumbo	20	150
Sand	25	175
Shale	15	190
Gumbo	35	225
Sand	30	255
Gumbo and shale	45	300
Sand	42	342
Gumbo	58	400
Sand	70	470
Gumbo	140	610
Sand	24	634

Well DH-64-18-111

Owner: W. F. Lawrence
Driller: Jim Avera

	THICKNESS (FEET)	DEPTH (FEET)
Clay	125	125
Shale	25	150
Shale, fine and sand streaks	16	166
Sand, fine	30	196

Well DH-64-18-407

Owner: F. A. Fards Estate
Driller: C. A. Williams

	THICKNESS (FEET)	DEPTH (FEET)
Clay	10	10
Sand, yellow	20	30
Gumbo	170	200
Sand	40	240
Gumbo	40	280
Sand and boulders	77	357
Gumbo and boulders	36	393
Shale and boulders	44	437
Gumbo, hard and lime	13	450
Shale	13	463
Sand, hard	2	465

	THICKNESS (FEET)	DEPTH (FEET)
Well DH-64-18-407—Continued		
Shale	2	467
Rock	3	470
Shale and boulders	4	474
Shale, sandy	34	508
Shale, hard	20	528
Sand	60	588
Shale	11	599
Gumbo	6	605
Sand, hard	5	610
Shale, hard and lime	95	705
Shale, broken and sand	25	730
Sand	25	755

Well DH-64-19-204

Owner: Humble Oil and Refining Co.
Driller: Pitre Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Clay, medium	72	72
Clay, hard	60	132
Sand, fine, soft	13	145
Clay, hard	13	158

Well DH-64-19-308

Owner: Layne-Bowler Co.
Driller: Layne-Bowler Co.

	THICKNESS (FEET)	DEPTH (FEET)
Loam	2	2
Clay	8	10
Sand	24	34
Clay	10	44
Sand	39	83
Clay	19	102
Gumbo	48	150
Shale, hard	19	169
Shale, soft	15	184
Shale, hard	13	197
Gumbo	7	204
Sand	46	250
Gumbo, blue	13	263
Sand	43	306
Gumbo, blue	23	329
Shale, hard	9	338
Shale, soft	11	349
Sand	7	356
Gumbo	13	369
Clay	7	376
Gumbo	23	399
Sand	33	432
Gumbo	4	436
Clay	6	442
Sand and gravel	32	474
Clay, blue	29	503
Shale	33	536
Sand	18	554
Gumbo	26	580
Shale	19	599
Gumbo	42	641
Shale, blue	3	644
Clay, tough	56	700
Gumbo	57	757
Shale	20	777
Sand	8	785
Gumbo	15	800
Sand	12	812
"Hard Pan"	8	820
Sand and gravel	31	851
Gumbo	18	869
No record	181	1,050

Well DH-64-19-609

Owner: Charlie Gilfillian
Driller: R. H. Schneider

	THICKNESS (FEET)	DEPTH (FEET)
Clay, yellow	24	24
Shale, blue	16	40
Shale, pink	22	62
Sand, fine	19	81

Well DH-64-19-911

Owner: E. A. Wilburn
Driller: Andy Frankland

	THICKNESS (FEET)	DEPTH (FEET)
Clay, yellow	18	18
Sand, fine	6	24

Table 5.—Drillers' Logs of Wells in Chambers and Jefferson Counties—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Well DH-64-19-911—Continued		
Clay, soft gray	254	278
Sand, streaks	11	289
Clay, blue	15	304
Sand with clay streaks	22	326
Well DH-64-20-408		
Owner: Mrs. James B. Jackson Driller: Andy Frankland		
Surface sand	24	24
Clay, yellow	61	85
Sand, fine	20	105
Clay, gray	165	270
Sand	4	274
Clay, soft	256	530
Sand	19	549
Well DH-64-20-601		
Owner: Sun Oil Co. Driller: R. H. Schneider		
Clay, yellow	20	20
Shale, blue	62	82
Sand	16	98
Shale, blue	92	190
Sand	24	214
Well DH-64-20-804		
Owner: Guy Jackson Driller: Amos Jennische		
Soil	3	3
Clay	77	80
Clay and shale	100	180
Gumbo	40	220
Shale	80	300
Sand	6	306
Shale	48	354
Sand	6	360
Gumbo	15	375
Sand	45	420

	THICKNESS (FEET)	DEPTH (FEET)
Well DH-64-21-204		
Owner: Frost Oil Co. Driller: Pitre Water Wells		
Clay, medium yellow	22	22
Sand, fine, soft	17	39
Clay, soft sandy	44	83
Sand, fine, soft	17	100
Shale, medium	58	158
Sand, medium soft	17	175
Sand, coarse and gravel	9	184
Clay, medium	11	195
Well DH-64-21-301		
Owner: Sun Oil Co. Driller: A-1 Water Wells		
Soil, surface black	2	2
Clay, yellow	16	18
Sand, fine, yellow	12	30
Sand, fine, blue	35	65
Shale, blue	91	156
Sand, water	38	194
Well DH-64-21-306		
Owner: Sun Oil Co. Driller: --		
Surface soil, black	2	2
Clay, yellow	20	22
Sands, fine yellow	11	33
Well DH-64-21-501		
Owner: Prince Drilling Co. Driller: Pitre Water Wells		
Sand	18	18
Shale	22	40
Unknown	20	60
Sand	96	156
Sand, fine	24	180
Shale	6	186

Table 5.—Drillers' Logs of Wells in Chambers and Jefferson Counties—Continued

Well DH-64-26-707

Owner: Humble Oil and Refining Co.
Driller: Humble Oil and Refining Co.

	THICKNESS (FEET)	DEPTH (FEET)
Sand and shale	456	456
Shale, sandy	27	483
Sand	74	557

Well DH-64-26-708

Owner: Humble Oil and Refining Co.
Driller: Humble Oil and Refining Co.

	THICKNESS (FEET)	DEPTH (FEET)
Shell and clay	160	160
Sand and clay	130	290
Shale	183	473
Sand and gravel	43	516
Shale	85	601
Sand	15	616
Shale	29	645
Gravel	18	663
Sand	47	710
No record	8	718

Well DH-64-26-905

Owner: J. E. Patton
Driller: Pitre Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Sand, brown	6	6
Clay, broken black	1½	7½
Sand, powder brown	10	17½
Log, brown	½	18
Sand, fine, vari-color	12	30
Shell, oyster and sand	3	33

Well DH-64-27-207

Owner: McCarthy Oil Co.
Driller: Pitre Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Sand, soft gray, fine	33	33
Clay, medium red	7	40
Clay, medium red, and sand	20	60
Shale, medium green	25	85
Sand, soft gray, fine	115	200
Sand, medium green and shale	22	222
Sand, soft gray	46	268
No record	146	414

Well DH-64-27-702

Owner: S. W. Mahoney
Driller: Andy Frankland

	THICKNESS (FEET)	DEPTH (FEET)
Surface sand	30	30
Clay, soft gray	60	90
Sand	36	126

Jefferson County

Well PT-61-56-702

Owner: Beaumont Country Club
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Clay, sandy	22	22
Clay, tough	184	206
Sand, white	41	247
Clay	30	277
Clay, sandy	37	314
Sand	26	340
Clay	28	368
Clay, sandy	16	384
Sand	20	404
Shale	130	534

Well PT-61-61-807

Owner: Southern Pacific Co.
Driller: Gust C. Warnecke

	THICKNESS (FEET)	DEPTH (FEET)
Clay	19	19
Sand	84	103
Clay	4	107
Sand	16	123
Clay	46	169
Sand	12	181
Clay	49	230
Loam, sandy	129	359
Sand	21	380
Clay	40	420
Sand	40	460
Shale, soft	182	642
Sand, water	50	692

Table 5.—Drillers Logs of Wells in Chambers and Jefferson Counties—Continued

	THICKNESS (FEET)	DEPTH (FEET)
Well PT-61-64-501		
Owner: Mobil Oil Co. Driller: Layne-Texas Co.		
Soil, surface and clay	25	25
Sand, red	28	53
Shale	62	115
Sand, gray	30	145
Shale	209	354
Sand and shale layers	32	386
Shale, sandy	45	431
Sand	25	456
Shale	39	495
Sand	10	505
Shale	3	508
Sand, water	110	618
Shale	2	620
Well PT-61-64-502		
Owner: Gulf States Utilities Co. Driller: Coastal Water Wells		
Topsoil	5	5
Sand	25	30
Shale	60	90
Shale and sand	30	120
Shale	30	150
Sand, fine	40	190
No record	40	230
Sand, coarse	30	260
No record	270	530
Shale, sandy	100	630
Well PT-61-64-504		
Owner: Olin Mathieson Co. Driller: Frank Balcar		
Clay	18	18
Sand	4	22
Shale	11	33
Gumbo	19	52
Sand	10	62
Gumbo	47	109
Sand	47	156
Gumbo	9	165
Sand	50	215
Shale	34	249
Sand	9	258
Gumbo	5	263
Sand and shale	45	308
Gumbo	16	324
Sand and shale	65	389
Gumbo	28	417
Sand	20	437
Gumbo	59	496
Sand with gravel at bottom	145	641
Well PT-61-64-505		
Owner: Mobil Oil Co. Driller: Texas Water Wells, Inc.		
Surface	4	4
Clay	28	32
Sand	7	39
Shale	32	71
Sand	14	85
Shale	11	96
Sand	51	147
Shale	153	300
Shale, sandy	56	356
Shale	56	412
Sand	35	447
Shale	61	508
Sand	125	633
Sand, shale streaked	27	660
Sand	178	838
Shale, sandy	71	909
Well PT-61-64-506		
Owner: Mobil Oil Co. Driller: Texas Water Wells, Inc.		
Surface	7	7
Clay	24	31
Sand, fine	3	34

	THICKNESS (FEET)	DEPTH (FEET)
Well PT-61-64-506—Continued		
Sand, clay streaks	64	98
Sand, gray	50	148
Clay	255	403
Sand, fine, hard	54	457
Shale	51	508
Sand, fine hard	45	553
Shale, sand streaks	41	594
Sand, fine, hard	39	633
Shale	29	662
Sand, very hard	171	833
Shale, sandy	63	896
Shale	12	908

Well PT-61-64-508

Owner: Gulf States Utilities Co.
Driller: Coastal Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Sand	15	15
Gumbo	30	45
Sand	15	60
Gumbo	13	73
Shale	87	160
Sand	100	260
Shale	60	320
Sand	30	350
Shale	40	390
Sand	50	440
Shale	40	480
Sand	80	560
Shale, sandy	240	800
Shale, gummy	800	1,600
Sand, fine	12	1,612

Well PT-61-64-510

Owner: Gulf States Utilities Co.
Driller: Coastal Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Sand	19	19
Gumbo	24	43
Sand	18	61
Gumbo	9	70
Shale, sandy	55	125
Gumbo	45	170
Sand, medium	75	245
Gumbo	3	248

Well PT-61-64-513

Owner: Mobil Oil Co.
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	3	3
Clay	68	71
Sand	12	83
Clay	13	96
Sand and clay, streaks	12	108
Sand	40	148
Clay	5	153
Sand, broken	20	173
Shale, sandy	3	176
Shale, sandy and sand, streaks	49	225
Sand	11	236
Clay, sandy	28	264
Sand and clay	17	281
Clay, sandy	31	312
Sand and clay, streaks	29	341
Sand and clay	20	361
Sand and clay, streaks	84	445
Clay, sandy	12	457
Sand, coarse	25	482
Shale and sand, streaks	32	514
Sand, hard, and shale, streaks	122	636
Shale	4	640

Well PT-61-64-803

Owner: Philip Bros.
Driller: Higgins Oil and Fuel Co.

	THICKNESS (FEET)	DEPTH (FEET)
Soil, black sandy loam	1	1
Clay, yellow with red streaks	13	14
Clay, blue with limy concretions	2	16
Sand, bluish-gray	6	22
Clay, yellowish-colored with lime	8	30
Clay, dark-blue with lime and shells	10	40

	THICKNESS (FEET)	DEPTH (FEET)
Well PT-61-64-803—Continued		
Sand, gray	16	56
Sand, blue	13	69
Clay, blue with pyrites	51	120
Sand, blue with some clay and small pebbles	26	146
Sand, fine bluish-gray	10	156
Sand, fine gray	31	187
Sand, fine gray with black specks	10	197
Sand, bluish-tinted gray	65	262
Sand, dark-gray with black specks	9	271
Sand, fine, dark-gray	44	315
Sand, fine grayish-tinted	35	350
Sand, fine, grayish-green	50	400
Sand, fine, brownish-gray	40	440
Sand, fine brown with shells	30	470
Sand, fine, brown with broken shells	21	491
Sand, coarse, blue with broken shells	9	500
Sand, very fine, muddy	47	547
Sand, very fine, bluish-gray	17	564
Sand, very fine, gray with bluish tint	48	612
Sand, fine, gray with bluish tint	12	624
Clay, fine, sandy (fishbones at 628 feet)	42	666
Clay, fine, blue, sandy	6	672
Sand, very fine, light blue	13	685
Rock, light blue	43	728
Sand, bluish-gray	8	736
Sand, light gray with shells	14	750
Marl with small shells	6	756
Sand, light bluish-gray and shells	5	761
Sand, fine and shells	64	825
Sand, very fine, dark brownish-gray	49	874
Clay, hard, grayish-blue, sandy with shells	26	900
Rock, dark-2 feet, shells-1 foot	3	903
Sand, dark grayish-blue with some clay	12	915
Lignite	5	920
Sand, bluish-gray with shells	34	954
Rock, bluish-gray	4	958
Sand, very fine, grayish-brown, with shells	24	982
Sand, very fine, with shells	13	995
Rock, dark gray, "Cap Rock"	5	1,000
Sand, coarse, dark-gray with oil	6	1,006
Well PT-61-64-804		
Owner: McFadden, Wiess & Kyle Driller: J. G. & A. W. Hamill		
Clay, yellow	36	36
Sand, coarse, gray	20	56
Clay, blue, hard	114	170
Sand, fine, gray	75	245
Gravel, vari-colored	20	265
Sand, coarse, gray	52	317
Clay, blue	35	352
Sand, coarse gray with pyrite concretions	24	376
Clay, blue	19	395
Sand, fine, gray with lignite	45	440
Marl	8	448
Sand, gray with concretions and much lignite	60	508
Limestone, soft	¾	508¾
Clay, gray and sulphurated hydrogen gas	19½	528¼
Sandstone, hard with calcite depositions	¾	529
Sand, gray	34	563
Sand, compact hard with pyrite	25	588
Sandstone, hard and calcareous concretions	½	588½
Clay, gray	13¼	601¾
Sand, hard	¼	602
Clay, gray with calcareous concretions	57	659
Shells, white, calcareous	6	665
Clay, gray	14	679
Sandstone, gray	6	685

	THICKNESS (FEET)	DEPTH (FEET)
Well PT-61-64-804—Continued		
Clay, gray, with calcareous concretions	7	692
Clay, gray, hard	23	715
Concretions, calcareous	2	717
Clay, hard, gray, with calcareous concretions and fine pyrite	136	853
Sandstone and pyrite, hard	20	873
Rock, hard, limestone	2	875
Sand, fine, oil	24	899
Clay, hard	80	979
Sandstone, hard with calcareous concretions	50	1,029
Gas, heavy pressure and oil	40	1,069
Sand, mixed with calcareous concretions and fossils	70	1,139
No record	21	1,160
Well PT-61-64-901		
Owner: Air Reduction Corporation Driller: Layne-Texas Co.		
Surface soil	3	3
Clay, sandy	57	60
Clay	11	71
Sand	31	102
Clay, sandy	47	149
Sand	12	161
Clay	5	166
Sand	20	186
Clay and sand streaks	215	401
Clay, sandy and sand streaks	51	452
Sand, coarse	34	486
Clay	4	490
Sand, fine	4	494
Clay	6	500
Sand, coarse (very good)	20	520
No record	20	540
Well PT-61-64-902		
Owner: Air Reduction Corporation Driller: Layne-Texas Co.		
Surface soil	4	4
Clay, sandy	65	69
Sand	28	97
Clay	51	148
Sand	13	161
Clay	4	165
Sand	20	185
Clay and streaks of sand	263	448
Sand, broken	42	490
Clay	7	497
Sand (good)	53	550
Well PT-61-64-903		
Owner: Big Three Industrial Gas Co. Driller: Layne-Texas Co.		
Top soil	3	3
Clay	18	21
Sand	14	35
Clay	35	70
Sand and sandy clay	83	153
Sand and streaks of clay	57	210
Sandy clay and streaks of sand	240	450
Sand	22	472
Clay	11	483
Sand	107	590
Well PT-61-64-904		
Owner: Big Three Industrial Gas Co. Driller: Layne-Texas Co.		
Top soil	3	3
Clay	57	60
Sand	34	94
Clay	15	109
Sand, clay and sandy clay	49	158
Sand, shell and sandy clay	68	226
Clay	20	246
Clay and sandy clay	108	354
Clay, sandy and clay	21	375
Clay	69	444
Sand	23	467
Clay	10	477
Sand, salt and pepper	284	761
Clay, sandy	19	780

Table 5.—Drillers' Logs of Wells in Chambers and Jefferson Counties—Continued

Well PT-62-57-703

Owner: Pure Oil Co.
Driller: --Walling

	THICKNESS (FEET)	DEPTH (FEET)
Clay	38	38
Sand and shale	73	111
Sand	15	126
Clay	10	136
Sand and clay	34	170
Clay	56	226
Sand	8	234
Sand and clay	38	272
Clay	18	290
Gumbo	20	310
Clay and shale	28	338
Clay	42	380
Clay and shale	13	393
Gumbo	74	467
Sand	17	484
Sand and clay	22	506
Sand	102	608

Well PT-62-57-704

Owner: Pure Oil Co.
Driller: --Walling

	THICKNESS (FEET)	DEPTH (FEET)
Mud and sand	70	70
Clay	45	115
Sand	20	135
Shale and clay	55	190
Sand and boulders	15	205
Sand	15	220
Clay	20	240
Sand and boulders	28	268
Clay	67	335
Gumbo	47	382
Clay	32	414
Gumbo	36	450
Sand	68	518
Gumbo	23	541
Sand	61	602

Well PT-62-57-706

Owner: Pure Oil Co.
Driller: --Walling

	THICKNESS (FEET)	DEPTH (FEET)
Sand and clay	150	150
Sand	22	172
Clay	90	262
Sand	21	283
Clay	154	437
Gumbo	20	457
Sand	61	518

Well PT-62-57-707

Owner: Pure Oil Co.
Driller: --Walling

	THICKNESS (FEET)	DEPTH (FEET)
Mud	22	22
Sand	119	141
Mud and sand	41	182
Mud	41	223
Clay	119	342
Gumbo	40	382
Clay	20	402
Gumbo	47	449
Sand	66	515
Gumbo	29	544
Sand	62	606

Well PT-62-57-709

Owner: Pure Oil Co.
Driller: --Walling

	THICKNESS (FEET)	DEPTH (FEET)
Mud and clay	28	28
Sand and shale	103	131
Clay	39	170
Sand and clay	14	184
Gumbo and boulders	44	228
Clay	17	245
Sand	5	250
Clay	108	358
Shale and clay	12	370
Gumbo	90	460
Sand and clay	28	488
Sand	117	605

	THICKNESS (FEET)	DEPTH (FEET)
Well PT-62-57-710		
Owner: Pure Oil Co. Driller: --Walling		
Clay	34	34
Sand and shale	84	118
Sand and clay	36	154
Gumbo	35	189
Shale and clay	35	224
Clay	31	255
Sand	21	276
Gumbo	61	337
Sand and shale	63	400
Gumbo	27	427
Sand and clay	47	474
Gumbo	30	504
Sand	106	610
Well PT-62-57-713		
Owner: Pure Oil Co. Driller: --Walling		
Mud	30	30
Sand	110	140
Sand and mud	40	180
Clay	65	245
Sand and clay	35	280
Clay	45	325
Gumbo	55	380
Clay	36	416
Gumbo	39	455
Sand	61	516
Gumbo	24	540
Sand	66	606
Well PT-63-01-104		
Owner: City of Nederland Driller: Frank Balcar		
Clay, yellow	32	32
Sand	6	38
Shale	22	60
Gumbo	10	70
Shale, blue	39	109
Sand	52	161
Shale	11	172
Gumbo, blue	13	185
Shale, gray	60	245
Rock, sand	1	246
Gumbo	24	270
Shale, hard	30	300
Gumbo	26	326
Rock	1	327
Shale, pink	23	350
Gumbo	32	382
Shale, hard	53	435
Shale, soft	23	458
Shale, sandy	22	480
Rock, shale	2	482
Sand, water	28	510
Well PT-63-01-202		
Owner: City of Port Arthur Driller: Layne-Bowler		
Clay	14	14
Quicksand	13	27
Sand, yellow	41	68
Sand, white, fine-grained, water	27	95
Clay	83	178
Sand, black, fine-grained	14	192
Clay, yellow	48	240
Sand, gray, medium-grained	43	283
Gumbo, blue	77	360
Sand, white, coarse-grained	14	374
Gumbo, hard	68	442
Pack sand, hard	185	627
Shale, hard	2	629
Well PT-63-01-204		
Owner: City of Port Arthur Driller: Layne-Bowler		
Clay	14	14
Quicksand	17	31
Clay, yellow	44	75

	THICKNESS (FEET)	DEPTH (FEET)
Well PT-63-01-204—Continued		
Sand, white, coarse-grained, water	27	102
Gumbo	83	185
Sand, blue, fine-grained	33	218
Gumbo, blue	38	256
Sand, gray, medium-grained	46	302
Gumbo, blue	18	320
Sand, white, medium-grained	32	352
Gumbo, hard	91	443
Sand, gray, fine-grained	34	477
Gumbo, blue	19	496
Sand, gray, medium-grained	80	576
Sand and gravel	80	656
Rock	1	657

Well PT-63-01-205

Owner: City of Port Arthur
Driller: Layne-Bowler

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	12	12
Quicksand	18	30
Gumbo, blue	48	78
Sand, blue, fine-grained	30	108
Sand, coarse-grained	51	159
Clay, yellow	37	196
Sand, blue, fine-grained	58	254
Gumbo, blue	59	313
Sand, fine-grained	33	346
Sand, heavy, white	30	376
Gumbo, hard, blue	90	466
Sand, blue, fine-grained	20	486
Sand, medium-grained and gravel	196	682

Well PT-63-01-206

Owner: City of Port Arthur
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Soil	3	3
Clay	80	83
Sand, and salt, white, coarse-grained	58	141
Shale, soft blue	189	330
Sand, gray, coarse-grained	55	385
Gumbo, soft blue	115	500
Sand with layers of gravel	137	637
Gravel, coarse	7	644

Well PT-63-01-302

Owner: Atlantic Refining Co.
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Clay	18	18
Clay, sandy	8	26
Clay	45	71
Shale	15	86
Sand, streaks, and shale	12	98
Shale	6	104
Sand, water	37	141
Shale	36	177
Sand	18	195
Shale	15	210
Sand	10	220
Gumbo	34	254
Shale, sticky	39	293
Shale and sand streaks	15	308
Sand and shale	13	321
Shale, tough, sticky	11	332
Sand and shale	5	337
Sand	10	347
Shale, tough	79	426
Sand	26	452
Shale	21	473
Sand layers, and shale	12	485
Sand	61	546
Shale	3	549

Well PT-63-01-303

Owner: Atlantic Refining Co.
Driller: --

	THICKNESS (FEET)	DEPTH (FEET)
Clay, yellow	18	18
Sand	12	30
Clay, yellow	23	53
Gumbo, soft	44	97

	THICKNESS (FEET)	DEPTH (FEET)
Well PT-63-01-303—Continued		
Gumbo, hard	20	117
Sand	34	151
Gumbo, blue	12	163
Sand	4	167
Gumbo	47	214
Sand	4	218
Gumbo and shale	264	482
Sand	30	512
Gumbo	40	552
Sand	38	590
Gravel	6	596
Shale, blue	111	707
Shale, sandy	23	730
Sand	26	756
Gravel	66	822

Well PT-63-01-305

Owner: Atlantic Refining Co.
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	1	1
Clay	9	10
Clay with sand streaks	51	61
Shale	18	79
Sand, small amount of water	19	98
Clay	4	102
Sand, water	40	142
Clay	33	175
Sand	18	193
Shale	20	213
Sand	7	220
Gumbo	26	246
Shale	5	251
Gumbo	12	263
Shale and gumbo streaks	50	313
Sand	11	324
Gumbo	3	327
Sand	12	339
Gumbo	17	356
Sand	2	358
Shale	65	423
Sand	28	451
Gumbo	15	466
Sand	82	548
Gumbo	52	600
Lime, sandy	10	610
Gumbo, sandy lime streaks	18	628
Shale	46	674
Gumbo	24	698
Sand, water	130	828
Gumbo	25	853
Sand	207	1,060
Gumbo	47	1,107
Shale	220	1,327
Sand	60	1,387
Gumbo	18	1,405
Shale, sticky	20	1,425
Sand	42	1,467
Shale, sticky	4	1,471

Well PT-63-01-505

Owner: Texas Highway Dept.
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Surface soil	6	6
Clay, blue	57	63
Sand	34	97
Clay	21	118
Sand	27	145
Clay	24	169
Sand	29	198
Clay and sand streaks	123	321
Sand and clay streaks	59	380
Sand	17	397
Clay	4	401
Sand and clay streaks	21	422
Clay, sandy and clay streaks	48	470
Clay	39	509
Clay, and sand streaks	31	540

	THICKNESS (FEET)	DEPTH (FEET)
Well PT-63-01-505—Continued		
Sand	20	560
Sand and hard streaks	40	600
Well PT-63-01-606		
Owner: City of Groves Driller: Layne-Texas Co.		
Soil	4	4
Clay	11	15
Clay, sandy	45	60
Clay	25	85
Sand, fine	12	97
Clay	26	123
Sand, fine	3	126
Shale and sandy shale	51	177
Sand, fine	5	182
Shale	32	214
Shale, sandy	16	230
Sand	11	241
Shale, sandy	230	471
Sand	5	476
Shale, sandy shale, and streaks of sand	269	745
Sand	126	871
Shale	15	886
No record	1	887
Well PT-63-01-701		
Owner: The Texas Co. Driller: --		
Clay, surface	20	20
Sand	10	30
Clay and sand	148	178
Sand and shale	113	291
Gumbo	18	309
Shale, sandy and boulders	131	440
Shale, hard	50	490
Gumbo	10	500
Sand	36	536
Gumbo	30	566
Sand and boulders	59	625
Rock, sand	22	647
Gumbo	23	670
Sand	14	684
Gumbo	16	700
Shale, sandy	15	715
Gumbo	88	803
Sand, fine-grained	37	840
Gravel, coarse	10	850
Sand, coarse-grained	10	860
Sand, fine-grained	48	908
Well PT-63-01-702		
Owner: The Texas Co. Driller: --		
Surface, clay	54	54
Shells	22	76
Shale	41	117
Gumbo	90	207
Shale	178	385
Gumbo	30	415
Shale, sandy	15	430
Gumbo	138	568
Shale	81	649
Gumbo	26	675
Shale	25	700
Gumbo	35	735
Shale	19	754
Gumbo	21	775
Shale, sandy	67	842
Sand, medium and coarse-grained, water	80	922
Gumbo	2	924
Well PT-63-01-703		
Owner: Olin Mathieson Co. Driller: Frank Balcar		
No formational record	756	756
Gumbo, blue and shale	84	840
Sand, blue and shale rock	15	855
Sand and gravel	80	935

	THICKNESS (FEET)	DEPTH (FEET)
Well PT-63-09-102		
Owner: Gulf Refining Co. Driller: Gulf Coast Drilling Co.		
Clay	150	150
Sand	30	180
Gumbo	36	216
Sand	14	230
Gumbo	110	340
Sand, and thin layers of lignite	110	450
Gumbo	64	514
Sand, hard	44	558
Gumbo	30	588
Sand	102	690
Gumbo	110	800
Shale	80	880
Sand, coarse-grained, water	64	944
Gumbo	2	946
Well PT-63-09-103		
Owner: Gulf Refining Co. Driller: Gulf Coast Drilling Co.		
Clay, blue and yellow	95	95
Shells	21	116
Shale	42	158
Gumbo	65	223
Sand and shale	143	366
Sand, hard	102	468
Gumbo	68	536
Shale	18	554
Gumbo	46	600
Shale	80	680
Gumbo	100	780
Shale	45	825
Sand and shale	55	880
Sand, water	82	962
Gumbo	3	965
Well PT-63-09-202		
Owner: Gulf State Utilities Co. Driller: Layne-Texas Co.		
Surface	3	3
Clay, sandy	102	105
Sand, coarse-grained, water	20	125
Clay	6	131
Sand	5	136
Clay	10	146
Sand	9	155
Clay	5	160
Clay, soft, sandy	5	165
Clay	58	223
Sand and shale	22	245
Shale, sandy and shell	36	281
Sand	12	293
Clay	45	338
Sand	20	358
Shale	17	375
Sand	33	408
Clay and sand	11	419
Sand	9	428
Clay	12	440
Sand	30	470
Clay	32	502
Sand	49	551
Wood	4	555
Sand	16	571
Clay	109	680
Sand	5	685
Clay	10	695
Sand	5	700
Shale	10	710
Sand	38	748
Shale	5	753
Sand	16	769
Shale	41	810
Sand	82	892
Shale	4	896
Sand and gravel, coarse-grained, water	47	943
Shale	10	953

	THICKNESS (FEET)	DEPTH (FEET)
Well PT-63-09-203		
Owner: Gulf State Utilities Co. Driller: Layne-Texas Co.		
No record	112	112
Clay	5	117
Sand	8	125
Clay	4	129
Sand	15	144
Clay	10	154
Sand	29	183
Clay	31	214
Sand, coarse-grained	36	250
Shale	124	374
Sand	36	410
Shale	80	490
Sand	52	542
Shale	51	593
Sand	10	603
Shale	97	700
Sand	14	714
Shale	32	746
Sand	15	761
Shale	16	777
Sand, water	104	881
Well PT-63-17-504		
Owner: W. O. Fawvor Driller: Works Project Administration		
Surface sand, reddish-brown	1	1
Sand, brown, fine-grained	6	7
Sand, brown and small shell fragments	1	8
Sand, brown, silty, fine-grained, and shell fragments	2	10
Sand, gray, fine-grained and shell fragments	5	15
Silt, blue, sandy	1	16
Silt, gray, sandy and small shell fragments	4	20
Clay, dark-gray, sticky	11	31
Shell, small, gray, hard packed	1	32
Clay, dark-gray, sticky and pieces of rock	1	33
Clay, hard, yellow	6	39
Clay, yellow, wet	2	41
Clay, hard, yellow	1	42
Clay, hard, brown, joint	6	48
Clay, hard, dark-brown	5	53
Clay, dark-blue, sticky	3	56
Clay, blue, sandy	1	57
Clay, soft blue and shell	1	58
Clay, soft blue	5	63
Clay, dark-gray, sandy and shell	2	65
Clay, dark-blue, sticky	6	71
Shells, small, gray	1	72
Shells, some large	1	73
Clay, dark-gray, sticky	5	78
Clay, hard, light-brown	2	80
Shells, dark-gray, and medium sized	1	81
Clay, hard, brown	1	82
Clay, light-brown	3	85
Clay, hard, dark-brown	3	88
Shale, hard, light-gray, limy bedded	3	91
Clay, black and lignite	1	92
Clay, tough, light-blue, sticky	8	100
Clay, hard, light-blue	1	101
Clay, blue, sandy	2	103
Clay, impervious hard, blue	1	104
Sand, dark-gray	1	105
Clay, compact, hard, brown	1	106
Sand, light-gray, fine-grained	2	108
Clay, gray, sandy and small shell	4	112
Clay, hard, dark-gray	3	115
Clay, gray, sandy	3	118
Clay, hard, dark, impervious	5	123
Clay, light-gray, sandy and some caliche	2	125
Clay, light-gray and yellow with shell and caliche	2	127
Clay, yellow and shell fragments	1	128
Sand, yellowish-gray, silty	1	129
Clay, gray, with hard pieces of shell and caliche	3	132

	THICKNESS (FEET)	DEPTH (FEET)
Well PT-63-17-504—Continued		
Clay, hard, light-blue with shell and caliche	3	135
Well PT-63-18-101		
Owner: Houston Oil Co. Driller: Gust C. Warnecke		
Mud, black and sand	60	60
Sand, salt water, no flow	115	175
Clay	277	452
Sand, flows 7 gallons a minute of salt water	46	498
Clay and shell mixed	533	1,031
Shell	4	1,035
Sand, flows salt water	30	1,065
Well PT-64-06-901		
Owner: I. R. Bordages Driller: V. R. Phelps		
Shale, sandy and clay	22	22
Sand, blue	46	68
Clay, blue	17	85
Clay, yellow	2	87
Sand, white	32	119
Shale, blue, chalky	75	194
Sand, gray, fine-grained	6	200
Well PT-64-07-203		
Owner: Ivy Senset Driller: Green Bros.		
Clay, yellow	20	20
Sand, yellow	5	25
Clay, yellow	40	65
Clay, blue	75	140
Sand, salt and pepper	16	156
Well PT-64-07-204		
Owner: P. A. Neichoy Driller: Green Bros.		
Clay, gray	29	29
Sand, red	6	35
Clay, blue	55	90
Clay, gray	20	110
Sand, water	45	155

	THICKNESS (FEET)	DEPTH (FEET)
Well PT-64-07-207		
Owner: Lizza Breaux Driller: Green Bros.		
Clay, green	20	20
Sand, white	10	30
Clay, gray	60	90
Clay, blue	25	115
Sand, water	40	155
Well PT-64-07-405		
Owner: Poley Mitchell Driller: Green Bros.		
Sand, red	20	20
Clay, yellow	60	80
Clay, blue	50	130
Sand, water	25	155
Well PT-64-14-101		
Owner: Union Texas Petroleum Co. Well 5 Driller: Layne-Texas Co.		
Soil, sandy	2	2
Clay, yellow	14	16
Sand, fine, loose, white	21	37
Sand, fine, gray, shale	21	58
Shale, gray, sandy, with some shell	20	78
Shale	35	113
Sand, broken, shale (poor)	33	146
Sand, loose, gray (good)	39	185
Sand, loose, gray (good)	26	211
Shale	11	222
Shale, thin layers	82	304
Well PT-64-14-406		
Owner: Union Texas Petroleum Co. Well 9 Driller: Layne-Texas Co.		
Surface soil	3	3
Clay	38	41
Sand, fine	7	48
Shale	48	96
Sand	29	125
Shale, broken	6	131
Sand	30	161

	THICKNESS (FEET)	DEPTH (FEET)
Well PT-64-14-406—Continued		
Shale, broken	7	168
Sand	37	205
Shale	52	257
Shale, sandy	15	272
Sand	16	288
Shale	11	299

Well PT-64-14-407

Owner: Union Texas Petroleum Co. Well 1
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Clay	12	12
Sand, white	35	47
Clay, and shale	64	111
Sand, cut clean	80	191
Shale	12	203
Sand, good	24	227
Sand, coarse	20	247
Shale	28	275

Well PT-64-15-202

Owner: C. E. Ward
Driller: Sun Oil Co.

	THICKNESS (FEET)	DEPTH (FEET)
Loam, brown, sandy	4	4
Shale, yellow	4	8
Clay, white, and shale	7	15
Clay, brown	6	21
Shale, brown, sandy	12	33
Sand, brown	3	36
Gumbo, blue	38	74
Gumbo, blue and yellow with red streaks	23	97
Sand	20	117

Well PT-64-15-306

Owner: Port Arthur Country Club
Driller: Pitre Water Wells

	THICKNESS (FEET)	DEPTH (FEET)
Surface sand, brown	2	2
Clay, vari-colored, hard	4	6
Sand, fine, white	5	11
Clay, sandy, brown	6	17
Sand, powder, brown	18	35
Clay, white, hard	13	48
Clay, blue, hard	7	55
Clay, and shell blue	28	83
Clay, brown, hard	8	91

Well PT-64-15-308

Owner: J. J. Hebert Heirs & Co.
Driller: Green Bros.

	THICKNESS (FEET)	DEPTH (FEET)
Clay, yellow	20	20
Sand, white	5	25
Clay, blue	35	60
Sand, salt and pepper	26	86

Well PT-64-15-603

Owner: Sun Oil Co.
Driller: N. H. Schnieder

	THICKNESS (FEET)	DEPTH (FEET)
Clay, yellow	30	30
Sand	11	41
Shale, blue	5	46
Sand, fine	15	61
Shale, blue	29	90
Sand	9	99
Shale, blue	1	100

Well PT-64-15-705

Owner: Pure Oil Co.
Driller: Layne-Texas Co.

	THICKNESS (FEET)	DEPTH (FEET)
Topsoil	2	2
Clay	30	32
Shale, blue and seashells	277	309
Sand, cut good	163	472
Shale	8	480

Table 6.—Water Levels in Wells in Chambers and Jefferson Counties
(Water level, in feet, below land surface)

Chambers County

Well DH-64-09-318

Owner: Crumpler Bros.
Elevation: 55

DATE		WATER LEVEL
Mar.	31, 1941	50.18
Mar.	1, 1948	66.87
Oct.	6	67.71
Apr.	27, 1949	67.15
Nov.	7	71.85
Nov.	3, 1950	77.23
Apr.	19, 1951	76.70
Oct.	15	79.00
Apr.	10, 1952	80.29
Oct.	10	82.18
Apr.	13, 1953	83.06
Oct.	16	84.57
Apr.	15, 1954	85.42
Oct.	13, 1955	83.07
Apr.	5, 1956	82.52

Well DH-64-09-319

Owner: Crumpler Bros.
Elevation: 55

DATE		WATER LEVEL
Mar.	31, 1941	43.16
Mar.	1, 1948	61.09
Apr.	10, 1952	79.20
Oct.	10	82.91
Apr.	13, 1953	83.70
Oct.	16	87.92
Apr.	5, 1956	94.19
Apr.	9, 1957	79.60

Well DH-64-09-901

Owner: S. R. Williams
Elevation: 15

DATE		WATER LEVEL
Mar.	1, 1948	47.70
Oct.	6	46.85
Apr.	27, 1949	42.40
Nov.	4	43.18
Apr.	12, 1950	47.54
Nov.	3, 1950	43.24
Apr.	19, 1951	48.76
Apr.	10, 1952	52.30
Oct.	10	52.32
Apr.	13, 1953	63.23
Oct.	16	65.76
Apr.	15, 1954	65.45
Oct.	13, 1955	68.64
Apr.	5, 1956	71.83
Oct.	13	83.23
Apr.	9, 1957	73.98
Oct.	31	73.14
Apr.	7, 1958	71.40
Oct.	23	74.21
Nov.	10, 1959	90.89
Apr.	10, 1961	95.83
Oct.	18	101.6
Oct.	10, 1962	110.0
Apr.	2, 1963	96.0
Oct.	28	111.2
Oct.	18, 1965	85.0
Mar.	16, 1967	101.9

Well DH-64-10-401

Owner: Finger
Furniture Co.
Elevation: 37

DATE		WATER LEVEL
Apr.	1955	86
Oct.	13	90.99
Apr.	5, 1956	88.34
Oct.	18	99.67
Apr.	5, 1957	92.26
Oct.	31	97.94
Apr.	7, 1958	94.60
Oct.	23	99.38
Nov.	9, 1959	101.63
Apr.	10, 1961	101.31
Oct.	18	103.66
Apr.	6, 1962	106.34
Oct.	22, 1962	107.57
Apr.	2, 1963	105.17
Oct.	31	116.28
Apr.	6, 1964	112.35
Oct.	14	121.27
Apr.	5, 1965	112.39
Oct.	18	115.02
Apr.	7, 1966	113.32
Oct.	12	117.27
Mar.	16, 1967	110.74

Well DH-64-10-403

Owner: C. D. Harman
Elevation: 26

DATE		WATER LEVEL
	1939	18
Mar.	5, 1941	18.07
Oct.	27, 1948	19.82
Nov.	7, 1949	19.66
Apr.	12, 1950	21.22
Nov.	3	21.90
Apr.	19, 1951	20.75
Oct.	15	21.46
Apr.	10, 1952	26.15
Oct.	10	22.79
Apr.	13, 1953	22.5
Apr.	15, 1954	24.53
Oct.	13, 1955	23.69

Well DH-64-10-501

Owner: C. T. Joseph, Jr.
Elevation: 33

DATE		WATER LEVEL
July	18, 1957	70.63
Oct.	14	69.55
Oct.	31	68.73
Apr.	7, 1958	66.10
Oct.	23	69.52
Nov.	9, 1959	67.29
Apr.	10, 1961	63.54
Apr.	6, 1962	65.67
Apr.	2, 1963	69.69

Well DH-64-10-501—Continued

DATE		WATER LEVEL
Apr.	7, 1964	40.25
Apr.	5, 1965	43.20
Apr.	7, 1966	40.22

Well DH-64-10-702

Owner: Texas Oil and Gas Co.
Elevation: 32

DATE		WATER LEVEL
Apr.	19, 1941	43.44
Oct.	5, 1948	58.40
Apr.	27, 1949	59.13
Nov.	3	60.58
Apr.	12, 1950	61.25
Nov.	3	64.80
Apr.	19, 1951	65.70
Oct.	15	67.80
Oct.	13, 1955	82.43
Oct.	18, 1956	89.75
Sept.	1965	106.5

Well DH-64-10-703

Owner: V. A. Lawrence
Elevation: 31

DATE		WATER LEVEL
Oct.	1938	38
Mar.	28, 1941	42.75
May	7, 1962	89.98
Oct.	22	96.70
Apr.	2, 1963	92.26
Oct.	28	99.87
Apr.	6, 1964	94.75
Oct.	14	103.97
Apr.	5, 1965	96.24
Oct.	18	106.91
Apr.	7, 1966	98.61
Oct.	12	104.27
Mar.	16, 1967	100.47

Well DH-64-11-103

Owner: Josh Mayes
Elevation: 9

DATE		WATER LEVEL
July	15, 1941	+ 6.2
Apr.	24	Flows
Nov.	18, 1948	4.74
Apr.	28, 1949	4.44
Nov.	8	5.65
Apr.	10, 1950	6.48
Nov.	1	7.45
Apr.	20, 1951	8.03
Oct.	11	9.11
Apr.	11, 1952	9.25
Oct.	9	10.78
Apr.	8, 1953	11.21
Oct.	15	12.40
Apr.	14, 1954	13.30

Well DH-64-11-401

Owner: E. S. Abshier
Elevation: 5

DATE		WATER LEVEL
Oct.	11, 1955	10.10
Apr.	4, 1956	9.07
Oct.	17	10.94
Apr.	5, 1957	9.53
Oct.	30	10.30
Apr.	10, 1958	8.42
Oct.	21	9.25
Nov.	9, 1959	9.03
Apr.	7, 1961	12.67
Oct.	19	14.77
Apr.	5, 1962	15.50
Oct.	23	16.05
Apr.	4, 1963	16.61
Oct.	30	17.33
Apr.	7, 1964	16.82
Oct.	14	19.02
Apr.	6, 1965	16.75
Oct.	19	18.92
Apr.	6, 1966	17.16
Mar.	15, 1967	17.36

Well DH-64-11-811

Owner: G. Chambliss
Elevation: 20

DATE		WATER LEVEL
Apr.	1947	12.0
Oct.	9, 1952	21.86
Apr.	8, 1953	20.54
Oct.	15	20.83
Apr.	14, 1954	21.20
Oct.	11, 1955	10.58
Apr.	4, 1956	19.23
Oct.	17	21.48
Apr.	5, 1957	20.11

Well DH-64-11-812

Owner: G. Chambliss
Elevation: 4

DATE		WATER LEVEL
July	24, 1941	4.89
Oct.	6, 1948	9.08
Apr.	28, 1949	5.92
Nov.	8	7.87
Apr.	10, 1950	7.82
Nov.	1	8.68
Apr.	20, 1951	6.90
Oct.	11	7.84
Apr.	11, 1952	4.14

Well DH-64-11-901

Owner: --Barringer
Elevation: 22

DATE		WATER LEVEL
May	2, 1941	6.22
Mar.	16, 1949	12.47
Aug.	31, 1950	13.34
Nov.	1	13.74
Apr.	20, 1951	14.17
Oct.	11	14.74
Apr.	11, 1952	14.92
Oct.	9	16.06

Table 6.—Water Levels in Wells in Chambers and Jefferson Counties—Continued
(Water level, in feet, below land surface)

Well DH-64-11-901—Continued

DATE		WATER LEVEL
Apr.	8, 1953	16.02
Oct.	15	16.76
Apr.	14, 1954	16.97
Apr.	4, 1956	19.55
Oct.	17	20.83
Apr.	5, 1957	22.15
Oct.	30	21.97
Apr.	10, 1958	21.32
Oct.	21	22.08
Nov.	3, 1959	22.86
Apr.	7, 1961	24.39
Oct.	19	25.51
Apr.	5, 1962	24.13
Oct.	23	25.41
Apr.	4, 1963	24.77
Oct.	30	25.62
Apr.	7, 1964	25.17
Apr.	6, 1965	25.84
Oct.	19	26.21
Apr.	6, 1966	26.34
Oct.	13	27.07
Mar.	15, 1967	27.15

Well DH-64-12-101

Owner: U.S. Dept. of Agriculture
Elevation: 28

DATE		WATER LEVEL
Apr.	15, 1941	9.35
Dec.	1, 1948	8.14
Nov.	8, 1949	8.55
Apr.	10, 1950	6.49
Nov.	1	7.44
Apr.	20, 1951	7.66
Oct.	11	8.47
Apr.	11, 1952	8.06
Oct.	9	8.93
Apr.	8, 1953	8.67
Oct.	15	9.65
Apr.	14, 1954	9.87
Oct.	11, 1955	9.29
Apr.	4, 1956	8.52
Oct.	17	9.37
Apr.	5, 1957	10.51
Oct.	30	9.94
Apr.	10, 1958	8.55
Oct.	21	8.87
Nov.	3, 1959	8.63
Apr.	7, 1961	7.31
Apr.	5, 1962	7.27
Apr.	4, 1963	8.51

Well DH-64-12-401

Owner: Sun Oil Co.
Elevation: 26

DATE		WATER LEVEL
Apr.	7, 1941	10.84
Apr.	14, 1954	17.13
Oct.	11, 1955	18.22
Apr.	4, 1956	18.46
Oct.	17	19.56
Apr.	5, 1957	19.32
Oct.	30	19.84
Apr.	10, 1958	20.43
Oct.	27	20.92
Nov.	3, 1959	21.97
Apr.	7, 1961	23.54
Oct.	19	23.42
Apr.	5, 1962	23.49
Oct.	23	24.10
Apr.	4, 1963	24.31
Oct.	30	24.36
Apr.	7, 1964	24.21
Oct.	14	24.87
Apr.	6, 1965	24.79
Apr.	6, 1966	25.16

Well DH-64-12-802

Owner: U.S. Dept. of Agriculture
Elevation: 25

DATE		WATER LEVEL
May	2, 1941	5.34
Dec.	1, 1948	11.81
Nov.	8, 1949	12.09
Apr.	10, 1950	12.60
Nov.	1	13.24
Apr.	20, 1951	13.46
Oct.	11	13.90
Apr.	8, 1953	15.16
Oct.	18	15.83
Apr.	14, 1954	16.07

Well DH-64-13-101

Owner: Oscar Devillier
Elevation: 34

DATE		WATER LEVEL
May	16, 1941	6.03
Mar.	15, 1948	6.85
Nov.	8, 1949	5.78
Apr.	10, 1950	8.15
Nov.	1	8.91
Apr.	23, 1951	9.05
Oct.	11	9.97
Apr.	11, 1952	10.86
Apr.	8, 1953	10.18
Apr.	14, 1954	10.97
Apr.	4, 1956	10.73
Oct.	17	11.06
Apr.	5, 1957	12.16
Oct.	30	11.03
Apr.	10, 1958	12.59
Oct.	21	12.71
Nov.	3, 1959	13.80
Apr.	7, 1961	11.94
Oct.	19	12.03
Apr.	5, 1962	12.19
Oct.	23	14.00
Apr.	4, 1964	14.01

Table 6.—Water Levels in Wells in Chambers and Jefferson Counties—Continued
(Water level, in feet, below land surface)

Well DH-64-13-101—Continued

DATE		WATER LEVEL
Oct.	30, 1964	15.21
Apr.	6, 1965	14.06
Oct.	19	15.73
Apr.	6, 1966	14.13
Oct.	5	13.95

Well DH-64-17-209

Owner: J. W. Wilburn
Elevation: 16

DATE		WATER LEVEL
	1931	20
Apr.	5, 1941	44.53
Aug.	31, 1950	80.60
Nov.	3, 1950	80.80
Apr.	19, 1951	82.01
Oct.	15	85.37
Apr.	10, 1952	85.65
Oct.	10	88.59
Apr.	13, 1953	89.73
Apr.	15, 1954	91.53

Well DH-64-17-301

Owner: The Texas Co.
Elevation: 24

DATE		WATER LEVEL
May	7, 1962	41.58
Oct.	22	43.23
Apr.	2, 1963	41.89
Oct.	28	45.07
Apr.	6, 1964	41.90
Oct.	14	46.72
Apr.	5, 1965	42.27
Apr.	7, 1966	43.54
Oct.	12	44.62
Mar.	16, 1967	43.82

Well DH-64-17-601

Owner: Asa Wilburn
Elevation: 15

DATE		WATER LEVEL
Apr.	5, 1941	15.88
Mar.	1, 1948	14.50
Oct.	6	14.48
Apr.	27, 1949	14.43
Nov.	7	14.75
Apr.	12, 1950	14.67
Nov.	3	14.90
Apr.	19, 1951	15.15
Oct.	15	15.18
Apr.	10, 1952	18.24
Oct.	10	15.68
Apr.	13, 1953	17.96
Oct.	16	18.49
Apr.	15, 1954	16.33
Oct.	13, 1955	18.94
Apr.	5, 1956	16.97
Oct.	18	21.46
Apr.	9, 1957	17.64
Oct.	31	16.30
Apr.	7, 1958	15.85
Oct.	23	16.52
Nov.	10, 1959	15.53
Apr.	10, 1961	16.78
Oct.	18	18.82
Apr.	6, 1962	17.33
Oct.	22	16.08
Apr.	2, 1963	17.28
Oct.	28	17.71
Mar.	16, 1967	15.53

Well DH-64-17-901

Owner: Seacrest Park
Elevation: 25

DATE		WATER LEVEL
Oct.	5, 1948	92.60
Apr.	27, 1949	93.45
Nov.	7	97.25
Apr.	12, 1950	97.32
Nov.	3	100.53
Apr.	19, 1951	101.10
Apr.	10, 1952	105.52
Oct.	10	106.91
Apr.	13, 1953	108.83
Oct.	16	110.1
Apr.	15, 1954	109.83
Oct.	13, 1955	116.85
Apr.	5, 1956	116.81
Oct.	18	122.79
Apr.	9, 1957	121.96
Oct.	31	124.34
Apr.	7, 1958	122.03
Oct.	23	125.82
Nov.	10, 1959	128.36
Apr.	10, 1961	130.81
Oct.	18	132.46
Apr.	6, 1962	133.16
Oct.	22	136.99
Apr.	2, 1963	136.11
Oct.	28	140.21
Apr.	6, 1964	139.52
Apr.	5, 1965	141.65
Oct.	18	144.84
Apr.	7, 1966	144.2
Oct.	12	146.5
Mar.	16, 1967	147.7

Well DH-64-17-910

Owner: Charles Kilgore
Elevation: 24

DATE		WATER LEVEL
	1939	55
Apr.	9, 1941	59.47
Mar.	1, 1948	88.30
Oct.	6	95.47
Aug.	31, 1950	102.70
Nov.	3	102.47
Apr.	19, 1951	104.26

Table 6.—Water Levels in Wells in Chambers and Jefferson Counties—Continued
(Water level, in feet, below land surface)

Well DH-64-17-910—Continued

DATE		WATER LEVEL
Apr.	10, 1952	108.53
Apr.	13, 1953	112.16
Oct.	13, 1955	120.45

Well DH-64-18-105

Owner: W. W. Pfistner
Elevation: 22

DATE		WATER LEVEL
	1928	21
Mar.	29, 1941	18.91
Oct.	5, 1948	21.38
Apr.	27, 1949	19.62
Nov.	4	21.78
Apr.	12, 1950	22.17
Nov.	3	22.75
Apr.	19, 1951	22.58
Oct.	15	23.00
Apr.	10, 1952	25.51
Oct.	10	23.92
Apr.	13, 1953	24.05
Oct.	16	24.84
Apr.	15, 1954	24.33
Apr.	5, 1956	25.98

Well DH-64-18-601

Owner: Humble Oil and Refining Co.
Elevation: 0

DATE		WATER LEVEL
May	29, 1958	32.2
May	21, 1962	37.90
Apr.	9, 1963	38.35
Apr.	17, 1964	39.85
June	16, 1965	40.9
Aug.	1, 1966	42.3
May	13, 1967	42.08

Well DH-64-18-602

Owner: Humble Oil and Refining Co.
Elevation: 0±

DATE		WATER LEVEL
Apr.	15, 1960	32.06
May	21, 1962	34.86
Apr.	9, 1963	34.46
Apr.	17, 1964	40.0
June	16, 1965	39.4
Aug.	1, 1966	41.41

Well DH-64-18-603

Owner: Humble Oil and Refining Co.
Elevation: 0±

DATE		WATER LEVEL
Apr.	15, 1960	34.69
May	21, 1962	35.74
Apr.	9, 1963	37.10
Apr.	17, 1964	40.4
June	16, 1965	37.9
Aug.	1, 1966	39.02
May	13, 1967	40.6

Well DH-64-18-902

Owner: Humble Oil and Refining Co.
Elevation: 0±

DATE		WATER LEVEL
May	15, 1942	4.40
Dec.	16, 1948	18.15
Aug.	25, 1950	22.91
May	4, 1951	24.74
May	20, 1952	24.95
Apr.	16, 1953	27.00
Apr.	29, 1954	28.77
Apr.	24, 1956	35.40

Well DH-64-19-904

Owner: R. Barrow
Elevation: 11

DATE		WATER LEVEL
	1940	Flowed
Mar.	17, 1948	2.84
Nov.	9, 1949	6.12
Apr.	11, 1950	13.94
Nov.	2	18.27
Apr.	23, 1951	19.65
Oct.	11	19.52

Well DH-64-20-301

Owner: U.S. Dept. of Agriculture
Elevation: 20

DATE		WATER LEVEL
May	22, 1941	5.54
Dec.	1, 1948	9.45
Nov.	8, 1949	8.81
Apr.	10, 1950	9.02
Nov.	1	6.06
Apr.	23, 1951	10.89
Oct.	11	10.58
Apr.	11, 1952	10.96
Oct.	9	12.38
Apr.	8, 1953	13.17
Oct.	15	11.6
Apr.	4, 1954	11.99
Oct.	11, 1955	15.3
Apr.	4, 1956	15.2
Nov.	3, 1959	19.35
Apr.	7, 1961	18.22

Well DH-64-22-402

Owner: U.S. Dept. of Agriculture
Elevation: 5±

DATE		WATER LEVEL
July	16, 1941	+ 2.9
Mar.	15, 1949	+ 0.49
Nov.	9	+ .42
Apr.	11, 1950	+ .41
Nov.	2	+ .46
Apr.	23, 1951	+ .80
Apr.	11, 1952	+ .70
Oct.	9	- .11
Oct.	22, 1953	- .46
Apr.	14, 1954	- .48

Well DH-64-26-704

Owner: Humble Oil and Refining Co.
Elevation: 0

DATE		WATER LEVEL
Apr.	14, 1960	68.0
May	21, 1962	69.24

Table 6.—Water Levels in Wells in Chambers and Jefferson Counties—Continued
(Water level, in feet, below land surface)

Well DH-64-26-704—Continued

DATE		WATER LEVEL
Apr.	9, 1963	69.77
Apr.	17, 1964	78.38
June	16, 1965	76.2
Aug.	1, 1966	76.75

Well DH-64-26-708

Owner: Humble Oil and Refining Co.
Elevation: 0

DATE		WATER LEVEL
Dec.	16, 1948	59.63
Aug.	25, 1950	58.87
May	4, 1951	58.56
May	20, 1952	61.61
May	20	61.79
May	20	61.59
Apr.	15, 1953	59.96
Apr.	29, 1954	62.47
Apr.	24, 1956	64.67
May	29, 1958	70.62

Well DH-64-27-201

Owner: Sun Oil Co.
Elevation: 5

DATE		WATER LEVEL
Apr.	1944	4
Mar.	17, 1949	4.60
Nov.	9	22.12
Apr.	11, 1950	7.22
Nov.	2	6.34
Apr.	23, 1951	6.27
Oct.	11	5.72
Apr.	11, 1952	6.09
Oct.	9	6.54
Apr.	8, 1953	5.99
Oct.	15, 1953	6.26
Apr.	14, 1954	6.82
Apr.	14	6.57
Oct.	11, 1955	6.45
Apr.	4, 1956	6.39
Oct.	17	6.75
Apr.	5, 1957	6.53
Oct.	30	6.58
Apr.	10, 1958	6.28
Oct.	21	6.64
Nov.	12, 1959	5.51
Apr.	3, 1962	6.15
Oct.	23	6.59
Apr.	4, 1963	6.36
Oct.	30	6.61
Apr.	7, 1964	6.41
Apr.	6, 1965	6.42
Apr.	6, 1966	6.58
Oct.	13	6.09
Mar.	15, 1967	6.56

Jefferson County

Well PT-63-01-301

Owner: L. J. Gibling
Elevation: 12

DATE		WATER LEVEL
May	18,1950	0.64
May	16, 1951	1.47
May	29, 1952	3.08
May	27, 1953	3.71
May	27, 1954	4.03
Dec.	14, 1955	7.68
May	28, 1957	9.09
May	21, 1958	10.57
Oct.	19, 1959	13.54
Oct.	10, 1960	14.96
May	10, 1962	18.07
Mar.	19, 1963	20.74
Feb.	6, 1964	22.96

Well PT-63-18-101

Owner: Houston Oil Co.
Elevation: 5

DATE		WATER LEVEL
	1906	+ 20
July	18, 1941	+ .72
May	18, 1950	5.52
May	16, 1951	4.39
May	29, 1952	3.31
May	27, 1953	3.48
May	27, 1954	3.98
Dec.	14, 1955	3.57
May	16, 1956	3.05
May	29, 1957	3.24
May	21, 1958	3.48
Oct.	19, 1959	2.39
Oct.	11, 1960	3.92
May	10, 1962	3.84
Mar.	20, 1963	10.26
Feb.	6, 1964	10.82
May	7, 1965	11.09

Well PT-64-06-401

Owner: Texas Pipeline Co.
Elevation: 25

DATE		WATER LEVEL
Jan.	28, 1942	+ 1.43
May	17, 1951	+ .32
June	5, 1952	+ .35
May	27, 1953	- .39
May	28, 1954	+ .01
Dec.	14, 1955	+ .31
May	16, 1956	+ .28
May	29, 1957	+ .46
Nov.	10, 1959	+ .19
Oct.	11, 1960	+ .13
May	9, 1962	+ .15
Mar.	19, 1963	+ .05
Feb.	6, 1964	+ .13
May	7, 1965	.09

Well PT-64-14-406

Owner: Union Texas Petroleum Co. Well 9
Elevation: 17

DATE		WATER LEVEL
Aug.	31, 1948	24
May	17, 1951	13.29
May	27, 1953	31.93

Table 6.—Water Levels in Wells in Chambers and Jefferson Counties—Continued
(Water level, in feet, below land surface)

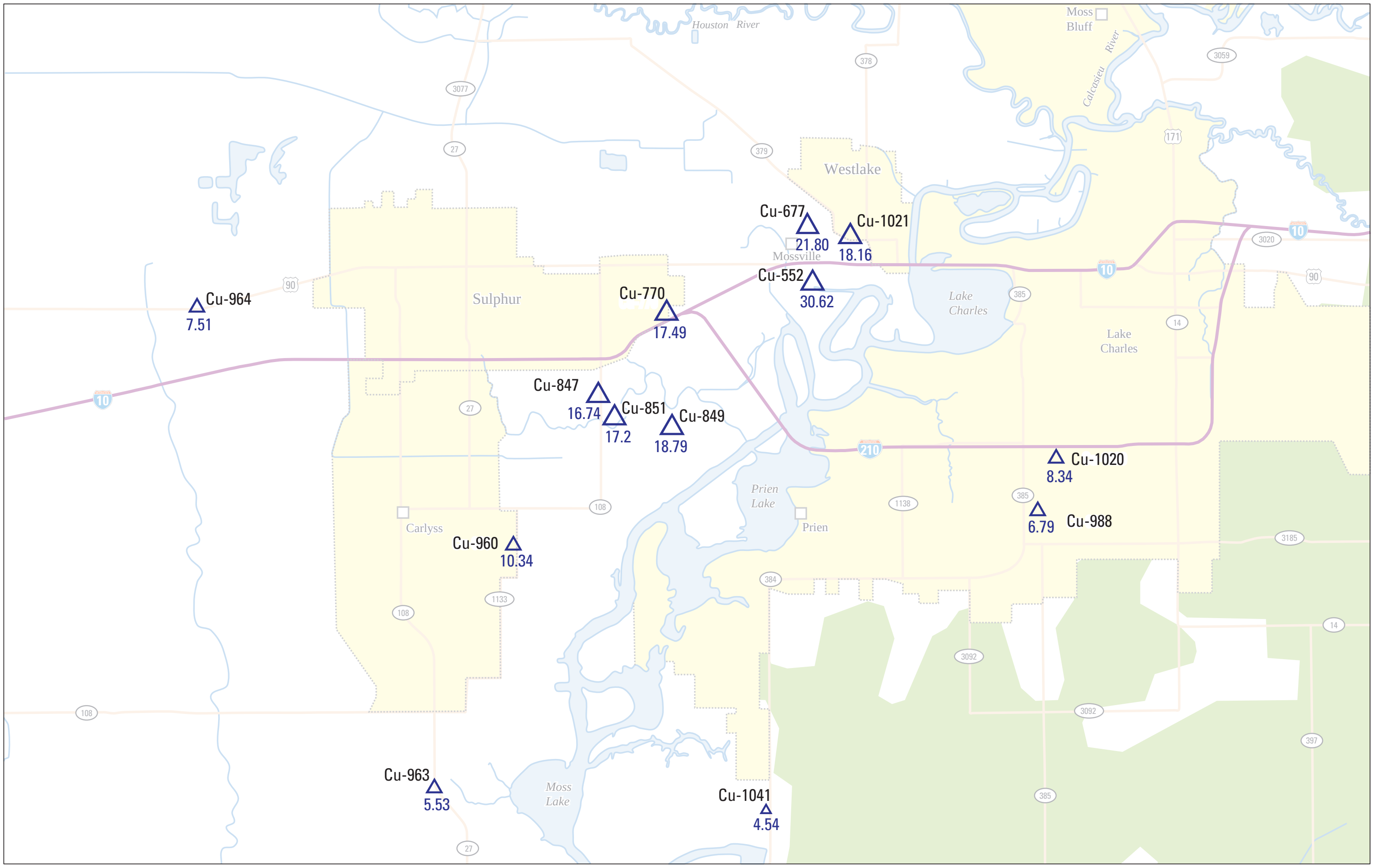
DATE		WATER LEVEL
Well PT-64-14-406—Continued		
Dec.	14, 1955	36.98
Nov.	4, 1959	45.08
Oct.	11, 1960	47.26
Well PT-64-22-301		
Owner: Pipkin Ranch Elevation: 5		
May	17, 1951	0.67
June	5, 1952	2.47
May	22, 1953	6.16
May	28, 1954	9.99
Dec.	14, 1955	8.91
May	16, 1956	7.74
May	29, 1957	9.80
May	21, 1958	9.42
Oct.	19, 1959	7.72
Oct.	11, 1960	14.64
Mar.	20, 1963	10.48
May	7, 1965	9.73
Well PT-64-23-103		
Owner: Pipkin Ranch Elevation: 5		
June	5, 1952	1.06
May	27, 1953	2.67
May	28, 1954	2.43
Dec.	14, 1955	3.54
May	16, 1956	3.53
May	29, 1957	4.37
May	21, 1958	5.01
Oct.	19, 1959	4.75
Oct.	11, 1960	6.58
May	10, 1962	7.42
March	20, 1963	8.01
Feb.	6, 1964	7.82
May	7, 1965	7.69

WHITE, V.E. AND GRIFFITH, J.M., 2020

POTENTIOMETRIC SURFACES, 2011-12 AND WATER-LEVEL DIFFERENCES BETWEEN 1995 AND 2011-12 IN WELLS IN THE "200-FOOT", "500-FOOT", AND "700-FOOT" SANDS OF THE LAKE CHARLES AREA, SOUTHWESTERN LOUISIANA

Prepared in cooperation with the Louisiana Department of Transportation and Development

Potentiometric Surfaces, 2011–12, and Water-Level Differences Between 1995 and 2011–12, in Wells of the "200-Foot," "500-Foot," and "700-Foot" Sands of the Lake Charles Area, Southwestern Louisiana



Pamphlet to accompany

Scientific Investigations Map 3460

U.S. Department of the Interior
U.S. Geological Survey

Potentiometric Surfaces, 2011–12, and Water-Level Differences Between 1995 and 2011–12, in Wells of the “200-Foot,” “500-Foot,” and “700-Foot” Sands of the Lake Charles Area, Southwestern Louisiana

By Vincent E. White and Jason M. Griffith

Prepared in cooperation with the Louisiana Department of Transportation and Development

Scientific Investigations Map 3460

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DAVID BERNHARDT, Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2020

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Contents

Figures

[All sheets available at https://doi.org/10.3133/sim3460]

Tables

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C = (°F – 32) / 1.8.

Datum

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Altitude, as used in this report, refers to distance relative to the vertical datum.

Supplemental Information

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Abbreviations

DOTD	Louisiana Department of Transportation and Development
USGS	U.S. Geological Survey

Potentiometric Surfaces, 2011–12, and Water-Level Differences Between 1995 and 2011–12, in Wells of the “200-Foot,” “500-Foot,” and “700-Foot” Sands of the Lake Charles Area, Southwestern Louisiana

By Vincent E. White and Jason M. Griffith

Abstract

Water levels were determined in 90 wells to prepare 2011–12 potentiometric surfaces focusing primarily on the “200-foot,” 500-foot,” and “700-foot” sands of the Lake Charles area, which are part of the Chicot aquifer system underlying Calcasieu and Cameron Parishes of southwestern Louisiana. These three aquifers provided 34 percent of the total water withdrawn and 93 percent of the groundwater withdrawn in Calcasieu and Cameron Parishes in 2012 (84.5 million gallons per day [Mgal/d]). This work was completed by the U.S. Geological Survey, in cooperation with the Louisiana Department of Transportation and Development, to assist in developing and evaluating groundwater-resource management strategies. The highest water levels determined in wells screened in the “200-foot,” “500-foot,” and “700-foot” sands were about 8 feet (ft) above the National Geodetic Vertical Datum of 1929 (NGVD 29), 2 ft below NGVD 29, and 14 ft below NGVD 29, respectively, and were located in northwestern Calcasieu Parish. The lowest water levels determined in wells screened in the “200-foot,” “500-foot,” and “700-foot” sands were approximately 50, 80, and 70 ft below NGVD 29, respectively, and were located in the southern Lake Charles metropolitan area, to the west of Prien Lake, and between the cities of Lake Charles and Sulphur, respectively. The primary groundwater flow direction in these three aquifers was radially towards pumping centers overlying the water-level lows. Comparisons of water-level differences in 42 wells measured in 1995 and 2011–12 indicated that the maximum increases in water levels for wells screened in the “200-foot,” “500-foot,” and “700-foot” sands were approximately 7, 31, and 19 ft, respectively. Water-level increases coincided with a decline in total groundwater withdrawals during the period (about 25 Mgal/d from 1995 to 2012) from these sands. More specifically, withdrawals from the “500-foot” sand affected water levels in wells screened in the “200-foot” and “700-foot” sands because the three are hydraulically connected and withdrawals from the “500-foot” sand were greater by volume than withdrawals from the “200-foot” and “700-foot” sands.

Introduction

Increases in groundwater withdrawals can lead to declining water levels and changes in flow directions and can affect water quality. Withdrawals from the Chicot aquifer system in the Lake Charles area of southwestern Louisiana (fig. 1), primarily from the “500-foot” sand, have caused long-term (years to decades) potentiometric-surface declines resulting in a cone of depression in the “500-foot” sand that extends across Calcasieu Parish. Because the “200-foot” and “700-foot” sands are hydraulically connected to the “500-foot” sand in this area, withdrawals from the “500-foot” sand have lowered water levels in wells screened in the “200-foot” and “700-foot” sands (figs. 2–4). Withdrawals have also caused hydraulic gradients favorable for encroachment of saltwater[1] towards fresh groundwater in the Lake Charles area (Lovelace, 1999).

Additional knowledge about groundwater levels, groundwater flow, and the effects of withdrawals on the “200-foot,” “500-foot,” and “700-foot” sands of the Lake Charles area is needed to assess the effects of withdrawals, determine the direction of groundwater flow, and develop sustainable groundwater-resource management strategies. To meet this need, the U.S. Geological Survey (USGS), in cooperation with the Louisiana Department of Transportation and Development (DOTD), began a study in 2011 to measure depth to water in a network of 90 wells in order to determine and document water levels in wells screened in the “200-foot,” “500-foot,” and “700-foot” sands and to prepare potentiometric surfaces and evaluate differences in water levels.

[1]Saltwater in this report is defined as water that contains chloride at concentrations of more than 250 milligrams per liter (mg/L). Concentrations of chloride less than 250 mg/L are within the secondary maximum contaminant level (SMCL) and are considered freshwater. The SMCLs are Federal guidelines regarding cosmetic effects (such as tooth or skin discoloration), aesthetic effects (such as taste, odor, or color), or technical effects (such as damage to water equipment or reduced effectiveness of treatment for other contaminants) of potential constituents of drinking water. The SMCLs were established as guidelines by the U.S. Environmental Protection Agency (2016).

Purpose and Scope

This report presents data, analysis, and maps that primarily describe the potentiometric surfaces of the “200-foot,” “500-foot,” and “700-foot” sands of the Lake Charles area during 2011–12. Water-level differences are calculated for select wells measured in both 1995 and 2011–12. In addition to the data presented in this report, water-level data are also available from the USGS National Water Information System database (U.S. Geological Survey, 2017a) and Louisiana Water-Use Program (U.S. Geological Survey, 2017b).

Description of Study Area

The study area (fig. 1) extends across about 2,300 square miles and includes all of Calcasieu Parish, the western two-thirds of Cameron Parish, and the extreme southwestern corner of Jefferson Davis Parish in southwestern Louisiana. The largest city in the study area, Lake Charles, had a 2010 population of about 72,000 (U.S. Census Bureau, 2019). Much of the study area is rural and agricultural, with rice production being a historically important agricultural sector (Louisiana State University AgCenter, 2015; fig. 1). Many and various industrial facilities are located near the Lake Charles metropolitan area, in the vicinity of the western bank of the Calcasieu River, and in Westlake. The climate is generally warm and temperate with high humidity and frequent rainfall. For the city of Lake Charles, the average annual temperature is 68 degrees Fahrenheit, and the average annual rainfall is about 56 inches (National Oceanic and Atmospheric Administration, 2011). Topographically, the study area is composed of a coastal plain, with the highest surface altitudes at about 90 feet (ft) above the National Geodetic Vertical Datum of 1929 (NGVD 29) at the northern border of the study area near DeQuincy and the lowest altitudes equivalent to about NGVD 29 at the southern border of the study area (U.S. Geological Survey, 2015).

Hydrogeologic Setting

The Chicot aquifer system underlies southwestern Louisiana and parts of southeastern Texas and is composed of a sequence of deposits of silt, sand, and gravel interbedded with clay and sandy clay that dips and thickens towards the south and southeast (fig. 3) (Nyman, 1984). The sand deposits grade southward from coarse sand and gravel to finer sediments and become increasingly subdivided by clay layers. A surficial clay confining layer overlies most of the Chicot aquifer system in southwestern Louisiana. Underlying the study area, the Chicot aquifer system is composed of various aquifers including the “200-foot,” “500-foot,” and “700-foot” sands, the upper and lower sands, and the undifferentiated sand (figs. 1 and 3). In addition, various shallow sands are present within a surficial confining layer (Lovelace, 1999).

The “200-foot,” “500-foot,” and “700-foot” sands are named for their general depths of occurrence in the Lake Charles area (Jones, 1950) and are located beneath central and western Calcasieu and Cameron Parishes (fig. 1) (Lovelace, 1998). Along the northern border of Calcasieu Parish, these sands merge into a single massive undifferentiated sand unit. The upper and lower sand units are in the eastern parts of Calcasieu and Cameron Parishes and are stratigraphically equivalent and hydraulically connected to the “200-foot” and the “700-foot” sands, respectively, in the Lake Charles area. Although the “500-foot” sand is stratigraphically equivalent to the lower sand unit of the Chicot aquifer system, it generally pinches out (disappears) to the east where it is commonly not directly hydraulically connected with the lower sand unit of the Chicot aquifer system (Lovelace, 1999).

Recharge to the Chicot aquifer system results from infiltration of precipitation primarily north of the study area (fig. 1 index map), where the aquifer system is at or near ground surface. In the recharge area, water percolates down into and through sandy surficial soil eventually reaching the “200-foot,” “500-foot,” and “700-foot” sands of the Lake Charles area (Nyman and others, 1990; Lovelace and others, 2001). Additional recharge is from leakage through vertically adjacent clay confining units (fig. 3).

Prior to extensive groundwater development in the study area during the 1940s, the movement of groundwater in the Chicot aquifer system as a whole was generally downgradient from north to south, and groundwater discharged into shallower aquifers or to the surface along the Sabine River and the Gulf of Mexico (Nyman and others, 1990). Since the 1940s, large withdrawals for industrial use, agriculture, and public supply primarily from the “200-foot,” “500-foot,” and “700-foot” sands of the Lake Charles area have caused water-level declines and altered the flow of groundwater in the study area. These declines have resulted in groundwater flowing towards the concentrated pumping in the vicinity of Lake Charles in Calcasieu Parish and towards agricultural areas (fig. 1) (Jones and others, 1954; Lovelace, 1998).

Methods

Potentiometric-surface maps were prepared based on water levels determined from 90 wells screened primarily in the “200-foot,” “500-foot,” and “700-foot” sands (table 1). Water levels were calculated by subtracting the depth-to-water measurement from the land-surface altitude and are referenced to NGVD 29. Seven nearby wells (Cu-971, Cu-5866Z, JD-485A, Cu-11708Z, Cu-10260Z, Cu-970, and Cu-1269) that were not screened in the “200-foot,” “500-foot,” and “700-foot” sands, but which were screened in hydraulically connected and stratigraphically equivalent sands (upper sand, lower sand, and undifferentiated sand) were used to create more complete potentiometric surfaces and water-level difference maps. Although used to present a more complete potentiometric surface, well Cu-11708Z was not used for analysis of minimum and maximum water levels because this well is screened in the undifferentiated sand in the northern part of the study area, where the “200-foot,” “500-foot,” and “700-foot” sands have merged. Cu-10260Z is coded as screened in the undifferentiated sand but is south of the approximate boundary between the undifferentiated sand and “200-foot” sand (fig. 1) and was treated accordingly.

Depth to water in each well was measured by using a steel or electrical tape marked with 0.01-ft gradations and were reported to one-hundredths of a foot, following procedures in Cunningham and Schalk (2011). Wells in which depth to water was measured were not being pumped at the time the measurements were made. If wells had been recently pumped, depth to water was measured after an appropriate recovery period. Water-level data were collected from December 2011 through March 2012; water levels in the study area typically decline (because of seasonal withdrawals) to their yearly low in June. Potentiometric contours were drawn as approximate around individual wells if the water levels differed appreciably from water levels in nearby wells or if data were sparse. Water levels determined during 1995 and 2011–12 at selected wells (table 1) were used to prepare water-level difference maps. When more than one measurement had been made at a selected well during those years, measurements made during the same time of year were preferentially chosen to minimize potential differences resulting from seasonal water-level fluctuations; however, same-season measurements were not always available.

Water-withdrawal data are collected collaboratively between the Louisiana DOTD and the USGS and made possible by the USGS Water Resources Cooperative Program: Louisiana Water-Use Program (U.S. Geological Survey, 2017b). Through this program, water-withdrawal data are collected from users or determined indirectly based on population size, agricultural-use types, and water-use coefficients. Totals are analyzed, compiled, and published by USGS on behalf of the Louisiana DOTD (U.S. Geological Survey, 2017b). Withdrawal data are provided to the public in several different combinations, such as by parish and aquifer, by State and aquifer, and by groundwater and parish; however, certain combinations and information are not published. Data that would reveal the exact location, such as address or latitude-longitude of withdrawal points, are not published in order to protect proprietary information. In addition, withdrawal data for individual sands within a larger aquifer or aquifer system are not published. For the purposes of this report, water use from each sand, the “200-foot,” 500-foot,” and “700-foot” sands, are disaggregated from the total withdrawal values from the Chicot aquifer. This facilitates a clearer understanding of the effects of withdrawals on the water-level altitude surfaces for each respective sand unit. For further information, contact either the Louisiana Water-Use Program USGS Lower Mississippi-Gulf Water Science Center, Baton Rouge office or the Louisiana DOTD Water Supply Availability and Use Program (Louisiana Department of Transportation and Development, 2018).

As with water-level data, withdrawal maps for the “200-foot,” “500-foot,” and “700-foot” sands included withdrawals from the relevant upper, lower, and undifferentiated sands of the Chicot aquifer system. In this report, the withdrawal maps only included values that were greater than an average of 0.1 million gallons per day (Mgal/d) at an individual well or a group of closely located wells. These values were provided to the Louisiana Water-Use Program and did not include indirectly determined values. Historical totals for groundwater withdrawals in the study area for 1960–2010 included the total groundwater withdrawals from all groundwater sources for Calcasieu and Cameron Parishes and have been provided to enable the reader to see current water-use values in their historical context. Historical totals for groundwater withdrawals in the study area for 1995–2012 included only withdrawals from the “200-foot,” “500-foot,” and “700-foot” sands.

Table 1. Water-level data from wells used to prepare the potentiometric surfaces (2011–12) and water-level difference (between 1995 and 2011–12) of the "200-foot," "500-foot," and "700-foot" sands of the Lake Charles area, southwestern Louisiana.

[USGS, U.S. Geological Survey; NGVD 29, National Geodetic Vertical Datum of 1929; mm, month; dd, day; yyyy, year; –, measurement not available during relevant time period; *, indicates that the well is screened in either the upper, lower, or undifferentiated sands of the Chicot aquifer system]

Well site name	USGS site number	Altitude of land surface, in feet above NGVD 29	Well depth, in feet below land surface	Date measured, mm/dd/yyyy	Depth to water level, in feet below land surface	Water-level altitude, in feet above or below (-) NGVD 29	Date measured, mm/dd/yyyy	Depth to water level, in feet below land surface	Water-level altitude, in feet above or below (-) NGVD 29	Difference, in feet between 1995 and 2011–12 value
"200-foot" sand										
				2011–12			1995			
Cu- 529	300818093361601	18	276	12/30/2011	51.88	-33.88	12/7/1995	53.91	-35.91	2.03
Cu- 768	301036093124402	11.53	306	12/15/2011	61.42	-49.89	–	–	–	–
Cu- 771	301336093183002	17.76	241	12/16/2011	55.40	-37.64	10/12/1995	60.73	-42.97	5.33
Cu- 798	300919093055601	25.43	345	3/7/2012	59.08	-33.65	–	–	–	–
Cu- 843	301148093193202	12	205	2/20/2012	48.23	-36.23	2/13/1995	51.74	-39.74	3.51
Cu- 946	301356093171001	15	198	3/6/2012	54.25	-39.25	9/28/1995	61.68	-46.68	7.43
Cu- 962	300812093165801	11	287	12/19/2011	48.60	-37.60	–	–	–	–
Cu- 975	301941093035602	20	237	12/21/2011	37.83	-17.83	11/29/1995	37.20	-17.20	-0.63
Cu- 984	300406093070001	15	325	3/7/2012	46.20	-31.20	–	–	–	–
Cu- 990	301059093125103	14	183	12/15/2011	57.73	-43.73	11/2/1995	60.68	-46.68	2.95
Cu-1101	301157093250501	12	260	2/14/2012	58.33	-46.33	–	–	–	–
Cu-11429Z	300545093163101	7	255	3/7/2012	40.35	-33.35	–	–	–	–
Cu-11872Z	301416093153501	11	202	2/21/2012	47.19	-36.19	–	–	–	–
Cu-12305Z	301445093164601	12	155	3/6/2012	43.51	-31.51	–	–	–	–
Cu-12600Z	300836093281801	11	280	12/29/2011	35.79	-24.79	–	–	–	–
Cu-12284Z	301016093224101	16	250	3/7/2012	51.11	-35.11	–	–	–	–
Cu-12933Z	301725093224101	22	110	3/7/2012	23.46	-1.46	–	–	–	–
Cu-1332	301033093205402	16	240	1/5/2012	58.69	-42.69	–	–	–	–
Cu-13320Z	301709093334401	27	280	2/21/2012	44.42	-17.42	–	–	–	–
Cu-13362Z	301201093404201	12	280	12/30/2011	34.02	-22.02	–	–	–	–
Cu-13571Z	301703093090501	13	180	3/5/2012	37.69	-24.69	–	–	–	–
Cu-6750Z	301512093171501	16	150	3/6/2012	48.71	-32.71	–	–	–	–
Cu-9584Z	301335093344401	23	280	1/12/2012	47.49	-24.49	–	–	–	–
Cn- 90	295611093044801	3.19	396	3/6/2012	31.62	-28.43	4/11/1995	23.92	-20.73	-7.70
Cn- 92	300104093015601	5.5	443	12/21/2011	38.99	-33.49	4/11/1995	29.66	-24.16	-9.33
Cu- 971*	300534092564402	5	500	12/22/2011	42.63	-37.63	11/21/1995	39.93	-34.93	-2.70
Cu-5866Z*	301118093004801	24	265	1/3/2012	61.22	-37.22	–	–	–	–
JD- 485A*	301300092584503	21	290	2/7/2012	57.57	-36.57	2/14/1995	50.95	-29.95	-6.62
Cu-11708Z*	302828093265801	88	260	1/10/2012	69.08	18.92	–	–	–	–
Cu-10260Z*	302059093402001	34	220	2/21/2012	26.36	7.64	–	–	–	–

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				“500-foot” sand						
				2011–12			1995			
Cu- 463B	301106093203202	17	516	1/5/2012	89.59	-72.59	–	–	–	–
Cu- 552	301359093162202	13	517	1/11/2012	85.63	-72.63	9/6/1995	116.25	-103.25	30.62
Cu- 677	301445093162201	10	568	3/6/2012	77.89	-67.89	9/20/1995	99.69	-89.69	21.80
Cu- 770	301336093183003	17.54	490	12/16/2011	85.05	-67.51	10/12/1995	102.54	-85.00	17.49
Cu-787	300353093210201	4.33	734	3/28/2012	48.60	-44.27	4/11/1995	50.59	-46.26	1.99
Cu- 828	301149093190801	10	560	1/5/2012	89.64	-79.64	–	–	–	–
Cu- 847	301230093193202	13	522	12/16/2011	81.87	-68.87	10/12/1995	98.61	-85.61	16.74
Cu- 849	301205093182501	10	564	1/4/2012	79.20	-69.20	10/11/1995	97.99	-87.99	18.79
Cu- 851	301213093191701	10	555	12/21/2011	80.75	-70.75	5/24/1995	97.9	-87.9	17.2
Cu- 895	301707093211601	18	355	12/13/2011	62.36	-44.36	–	–	–	–
Cu- 947	300643093044701	20	600	12/15/2011	59.78	-39.78	11/29/1995	58.89	-38.89	-0.89
Cu- 957	301120093191002	17	500	1/5/2012	90.37	-73.37				
Cu- 960	301031093204902	21	598	12/16/2011	85.48	-64.48	10/11/1995	95.82	-74.82	10.34
Cu- 961	301214093223201	14	540	2/20/2012	55.86	-41.86	–	–	–	–
Cu- 963	300718093220001	10	399	12/29/2011	61.53	-51.53	12/7/1995	67.06	-57.06	5.53
Cu- 964	301339093253901	16	360	12/29/2011	56.43	-40.43	11/22/1995	63.94	-47.94	7.51
Cu- 977	301944093170402	20	515	12/20/2011	47.83	-27.83	11/22/1995	54.44	-34.44	6.61
Cu- 988	301059093125101	14	523	12/15/2011	74.69	-60.69	11/2/1995	81.48	-67.48	6.79
Cu-1018	301800093121701	20	398	12/13/2011	54.47	-34.47	–	–	–	–
Cu-1019	300354093205501	5	700	3/6/2012	53.84	-48.84	–	–	–	–
Cu-1020	301141093123501	18	375	12/15/2011	77.68	-59.68	11/2/1995	86.02	-68.02	8.34
Cu-1021	301435093154601	12	487	12/19/2011	75.27	-63.27	10/12/1995	93.43	-81.43	18.16
Cu-1041	300702093165801	9	560	12/15/2011	65.18	-56.18	11/2/1995	69.72	-60.72	4.54
Cu-1051	301401093302401	20	410	2/2/2012	53.23	-33.23	12/13/1995	57.42	-37.42	4.19
Cu-1055	301450093251501	15	520	2/2/2012	55.27	-40.27	–	–	–	–
Cu-11500Z	302127093102801	34	250	12/14/2011	54.97	-20.97	–	–	–	–
Cu-1160	301559093374601	25	526	2/1/2012	46.50	-21.50	–	–	–	–
Cu-11708Z*	302828093265801	88	260	1/10/2012	69.08	18.92	–	–	–	–
Cu-12287Z	300822093321201	10	460	2/2/2012	43.44	-33.44	–	–	–	–
Cu-12469Z	301753093300501	26	250	2/1/2012	59.47	-33.47	–	–	–	–
Cu-12489Z	301401093063201	17	460	12/14/2011	56.77	-39.77	–	–	–	–

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"500-foot" sand—Continued										
				2011–12—Continued			1995			
Cu-1267	301852093393901	30	405	12/14/2011	32.43	-2.43	–	–	–	–
Cu-1319	301359093160701	15	510	1/11/2012	85.35	-70.35	–	–	–	–
Cu-1328	301420093130301	16	495	3/8/2012	79.70	-63.70	–	–	–	–
Cu-13524Z	301031093255301	10	470	2/20/2012	54.23	-44.23	–	–	–	–
Cu-13585Z	301628093073601	15	300	12/14/2011	44.49	-29.49	–	–	–	–
Cn- 87	295324093240602	8.46	804	3/6/2012	44.26	-35.80	–	–	–	–
Cn- 88L	300055093093004	8.86	804	12/15/2011	48.49	-39.63	4/11/1995	45.49	-36.63	-3.00
Cn- 120	295721093115701	3	764	3/6/2012	37.50	-34.50	–	–	–	–
Cn- 134	295839093203501	5	710	3/6/2012	43.16	-38.16	–	–	–	–
"700-foot" sand										
				2011–12			1995			
Cu- 746	301300093161601	4.09	780	1/11/2012	70.16	-66.07	10/20/1995	89.51	-85.42	19.35
Cu- 767	301036093124401	11.42	850	12/15/2011	68.31	-56.89	4/10/1995	69.46	-58.04	1.15
Cu- 769	301336093183001	17.62	642	12/16/2011	84.85	-67.23	4/10/1995	97.52	-79.90	12.67
Cu- 788	300825093260801	6.11	805	12/19/2011	52.37	-46.26	11/22/1995	54.67	-48.56	2.30
Cu- 811	300812093165802	11	923	12/19/2011	65.71	-54.71	–	–	–	–
Cu- 958	301944093170401	20	707	12/20/2011	46.23	-26.23	11/30/1995	52.55	-32.55	6.32
Cu- 959	301031093204901	21	733	12/16/2011	82.22	-61.22	10/11/1995	92.01	-71.01	9.79
Cu- 972	301941093035601	20	595	12/21/2011	43.27	-23.27	11/29/1995	42.38	-22.38	-0.89
Cu- 978	301409093120301	15	645	12/20/2011	68.14	-53.14	11/1/1995	77.24	-62.24	9.10
Cu- 994	300634093400401	5	757	12/20/2011	40.77	-35.77	12/8/1995	33.00	-28.00	-7.77
Cu-1022	301444093162901	11	618	1/4/2012	77.48	-66.48	9/28/1995	95.78	-84.78	18.30
Cu-11708Z*	302828093265801	88	260	1/10/2012	69.08	18.92	–	–	–	–
Cu-1239	302106093115401	25	502	3/5/2012	47.83	-22.83	11/30/1995	54.08	-29.08	6.25
Cu-12894Z	300404093115801	10	520	2/20/2012	50.91	-40.91	–	–	–	–
Cu-1388	301852093393902	30	585	12/30/2011	44.13	-14.13	12/12/1995	44.50	-14.50	0.37
Cu-1419	301331093172801	12	620	3/6/2012	81.59	-69.59	–	–	–	–
Cn- 94	294543093391401	6.22	1,118	3/6/2012	37.98	-31.76	–	–	–	–
Cn- 119	294709093174302	3.5	910	3/6/2012	25.62	-22.12	–	–	–	–
Cu- 970*	300534092564401	5	780	12/22/2011	43.33	-38.33	11/21/1995	40.19	-35.19	-3.14
[1]Cu-1269*	301414093004501	22	503	1/3/2012	86.60	-64.60	12/12/1995	63.84	-41.84	-22.76

[1]Nearby site that taps the same aquifer was being pumped for both the 1995 and 2011–12 values.

Potentiometric Surfaces and Water-Level Differences in Wells of the “200-Foot” Sand

Water levels in the “200-foot” sand generally were highest in northern Calcasieu Parish and lowest in the southern part of the city of Lake Charles; the highest water level was 7.64 ft above NGVD 29 at well Cu-10260Z (table 1; fig. 5),[2] and the lowest water level was 49.89 ft below NGVD 29 at well Cu-768 (fig. 5). The direction of groundwater flow in much of the aquifer was generally from north to south and radially towards a shallow cone of depression delineated by the −40-ft contour on figure 5. Although there are water-withdrawal sites in the “200-foot” sand in the vicinity of the cone of depression (fig. 6; table 2), the cone is primarily the result of much heavier pumping in this same area from the “500-foot” sand (fig. 7; table 3), which is hydraulically connected to and affects water levels in wells screened in the “200-foot” sand as can be seen in the historical water use and water levels in the “200-foot,” “500-foot,” and “700-foot” sands (fig. 4; table 4).

Water-level differences in wells screened primarily in the “200-foot” sand indicate increases of as much as 7.4 ft at wells in the Lake Charles metropolitan area and in western Calcasieu Parish (fig. 8; table 1) from 1995 to 2011, whereas water levels declined as much as 9 ft at wells near the eastern border of the study area during the same period. The water-level increases were primarily the result of reduced withdrawals from the “500-foot” sand; withdrawals from the “200-foot” sand changed little from 1995 to 2011–12 (fig. 4). The water-level declines along the eastern border of the study area could be the result of seasonal fluctuations or increased withdrawals from the Chicot aquifer upper sand in neighboring Jefferson Davis Parish, where groundwater withdrawals increased from 66.03 Mgal/d in 1995 to 90.18 Mgal/d in 2012 (U.S. Geological Survey, 2017b).

[2]As mentioned previously in Methods, well Cu-11708Z was not included in the max-min analysis.

Table 2. Withdrawals from the "200-foot" sand of the Lake Charles area and upper and undifferentiated sands of the Chicot aquifer system, southwestern Louisiana, 2010.

Site number[1]	Parish	Withdrawal rate, in million gallons per day (Mgal/d)	Aquifer
A2	Calcasieu	0.6	undifferentiated sand
B2	Calcasieu	0.5	“200-foot” sand
C2	Calcasieu	0.1	“200-foot” sand
D2	Calcasieu	1.0	“200-foot” sand
E2	Calcasieu	0.3	“200-foot” sand
F2	Calcasieu	0.1	“200-foot” sand
G2	Calcasieu	0.1	“200-foot” sand
H2	Cameron	0.2	“200-foot” sand
I2	Cameron	0.2	“200-foot” sand
J2	Cameron	0.1	upper sand
K2	Cameron	0.4	upper sand

[1]See figure 6.

Table 3. Withdrawals from the “500-foot” sand of the Lake Charles area, southwestern Louisiana, 2010.

Site number[1]	Parish	Withdrawal rate, in million gallons per day (Mgal/d)	Aquifer
A5	Calcasieu	2.3	“500-foot” sand
B5	Calcasieu	0.6	“500-foot” sand
C5	Calcasieu	1.5	“500-foot” sand
D5	Calcasieu	2.8	“500-foot” sand
E5	Calcasieu	6.5	“500-foot” sand
F5	Calcasieu	1.6	“500-foot” sand
G5	Calcasieu	1.5	“500-foot” sand
H5	Calcasieu	0.4	“500-foot” sand
I5	Calcasieu	20.7	“500-foot” sand
J5	Calcasieu	0.7	“500-foot” sand
K5	Calcasieu	0.5	“500-foot” sand
L5	Calcasieu	1.0	“500-foot” sand
M5	Calcasieu	1.4	“500-foot” sand
N5	Calcasieu	0.1	“500-foot” sand
O5	Calcasieu	9.7	“500-foot” sand
P5	Calcasieu	11.6	“500-foot” sand
Q5	Calcasieu	2.5	“500-foot” sand
R5	Calcasieu	1.7	“500-foot” sand
S5	Calcasieu	0.4	“500-foot” sand
T5	Cameron	0.1	“500-foot” sand
U5	Cameron	0.2	“500-foot” sand
V5	Cameron	0.2	“500-foot” sand
W5	Cameron	0.2	“500-foot” sand

[1]See figure 7.

Table 4. Withdrawals, in million gallons per day (Mgal/d), from the “200-foot,” “500-foot,” and “700-foot” sands of the Lake Charles area, southwestern Louisiana, 1994–2012.

Year	“200-foot” sand (Mgal/d)	“500-foot” sand (Mgal/d)	“700-foot” sand (Mgal/d)	Total (Mgal/d)
1995	9.18	90.37	9.82	109.36
2000	19.45	95.74	9.79	124.97
2005	11.76	71.11	4.81	87.68
2010	9.68	72.38	3.22	85.28
2012	9.34	71.93	3.24	84.51

Potentiometric Surfaces and Water-Level Differences in Wells in the “500-Foot” Sand

Water levels in the “500-foot” sand generally were highest in northern Calcasieu Parish and lowest between Carlyss and Prien. The highest of the 40 water levels determined in wells screened in the “500-foot” sand was 2.43 ft below NGVD 29 at well Cu-1267 in northwestern Calcasieu Parish (fig. 9).[3] The lowest water level in the “500-foot” sand, 79.64 ft below NGVD 29, was determined at well Cu-828, located about 2 miles west-northwest of Prien Lake (fig. 10). Water levels were more than 40 ft below NGVD 29 in most of the Lake Charles metropolitan area. A large cone of depression centered on the area between Lake Charles and Prien Lake comprises two smaller cones of depression underlying major pumping centers (fig. 7), where water levels were 70–80 ft below NGVD 29. The general direction of flow in the “500-foot” sand during 2011–12 was radially towards these pumping centers.

Water-level differences at wells screened in the “500-foot” sand indicate increases of as much as 6.6 ft outside of the Lake Charles metropolitan area, with minor decreases at two wells located southeast of the metropolitan area (fig. 11). In the metropolitan area, water-level increases were more substantial, rising over 30 ft (fig. 12). The water-level increases in wells screened in the metropolitan area resulted from reduced withdrawals from the “500-foot” sand, which declined from 90.37 Mgal/d in 1995 to 71.93 Mgal/d in 2012 (fig. 4; table 4).

[3]As mentioned previously in *Methods*, well Cu-11708Z was not included in the max-min analysis.

Potentiometric Surfaces and Water-Level Differences in Wells in the “700-Foot” Sand

Water levels in the “700-foot” sand generally were highest in northern Calcasieu Parish and lowest near the Calcasieu River north of Prien. The highest water level was 14.13 ft below NGVD 29 at well Cu-1388 (fig. 13; table 1),[4] and the lowest water level was 69.59 ft below NGVD 29 at well Cu-1419. The potentiometric surface was more than 50 ft below NGVD 29 in most of the Lake Charles metropolitan area. The direction of groundwater flow in much of the aquifer was generally radial towards the cone of depression underlying the metropolitan area (fig. 13). Comparatively, there was little pumping from the “700-foot” sand or lower sand within the cone of depression (fig. 14; table 5), and the cone is the result of heavier pumping from the “500-foot” sand (fig. 7; table 3), which is hydraulically connected to and affects water levels in the “700-foot” sand.

Water-level differences at wells screened primarily in the “700-foot” sand of the Lake Charles area indicate increases of about 19 ft in the north-central part of the study area; however, water levels decreased at wells near the eastern edge of the study area and in southwestern Calcasieu Parish (fig. 15). Although withdrawals from the “700-foot” sand decreased from 9.82 Mgal/d in 1995 to 3.24 Mgal/d in 2012 (fig. 4), the water-level increases were primarily the result of reduced withdrawals from the “500-foot” sand. The large water-level decline at well Cu-1269 at the town of Iowa (fig. 15) was probably the result of pumping at a nearby well when the 2011 water level was determined and not indicative of broader declines in the aquifer in that area. The other declines near the eastern border were relatively small and could have resulted from seasonal water-level variation. The cause of the 7.77-ft decline in southwestern Calcasieu Parish is undetermined.

[4]As mentioned previously in *Methods*, well Cu-11708Z was not included in the max-min analysis.

Table 5. Withdrawals from the “700-foot” sand of the Lake Charles area and lower sand of the Chicot aquifer system, southwestern Louisiana, 2010.

Site number[1]	Parish	Withdrawal rate, in million gallons per day (Mgal/d)	Aquifer
A7	Calcasieu	0.9	“700-foot” sand
B7	Calcasieu	1.0	“700-foot” sand
C7	Calcasieu	0.3	lower sand

[1]See figure 14.

Summary

The "200-foot," "500-foot," and "700-foot" sands of the Chicot aquifer system underlying southwestern Louisiana are an important source of freshwater in the Lake Charles metropolitan area and the surrounding communities in Calcasieu and Cameron Parishes in southwestern Louisiana. Potentiometric surfaces, water-level difference maps, and concurrent water-withdrawal data are important to help assess the effects of withdrawals, determine the direction of groundwater flow, and develop sustainable groundwater-resource management strategies. To meet this need, the U.S. Geological Survey, in cooperation with the Louisiana Department of Transportation and Development, began a study in 2011 to measure depth to water in a network of 90 wells in order to determine and document water levels in wells screened in the "200-foot," "500-foot," and "700-foot" sands; prepare potentiometric-surface maps; and evaluate differences in the water levels between 1995 and 2011–12.

The lowest water levels in Calcasieu and Cameron Parishes in wells screened in the "200-foot," "500-foot," and "700-foot" sands were approximately 50, 80, and 70 feet (ft) below the National Geodetic Vertical Datum of 1929 (NGVD 29), respectively, and were located specifically in the southern Lake Charles metropolitan area, to the west of Prien Lake, and between the cities of Lake Charles and Sulphur, respectively. The highest water levels in Calcasieu and Cameron Parishes occurring in wells screened in the "200-foot," "500-foot," and "700-foot" sands were approximately 8 ft above NGVD 29, 2 ft below NGVD 29, and 14 ft below NGVD 29, respectively, and were all located in northwestern Calcasieu Parish.

The distribution of water levels in the "200-foot," "500-foot," and "700-foot" sands indicates a primary flow direction towards pumping centers overlying the water-level lows. Between 1995 and 2011–12, maximum water-level increases were approximately 7 ft in the "200-foot" sand, approximately 31 ft in the "500-foot" sand, and approximately 19 ft in the "700-foot" sand. Water-level increases are consistent with a reduction in total withdrawals from these aquifers of about 25 million gallons per day from about 109 million gallons per day in 1995 to about 85 million gallons per day in 2012. Groundwater withdrawals from the "500-foot" sand are the highest by volume and the most influential over water levels in the "200-foot" and "700-foot" sands.

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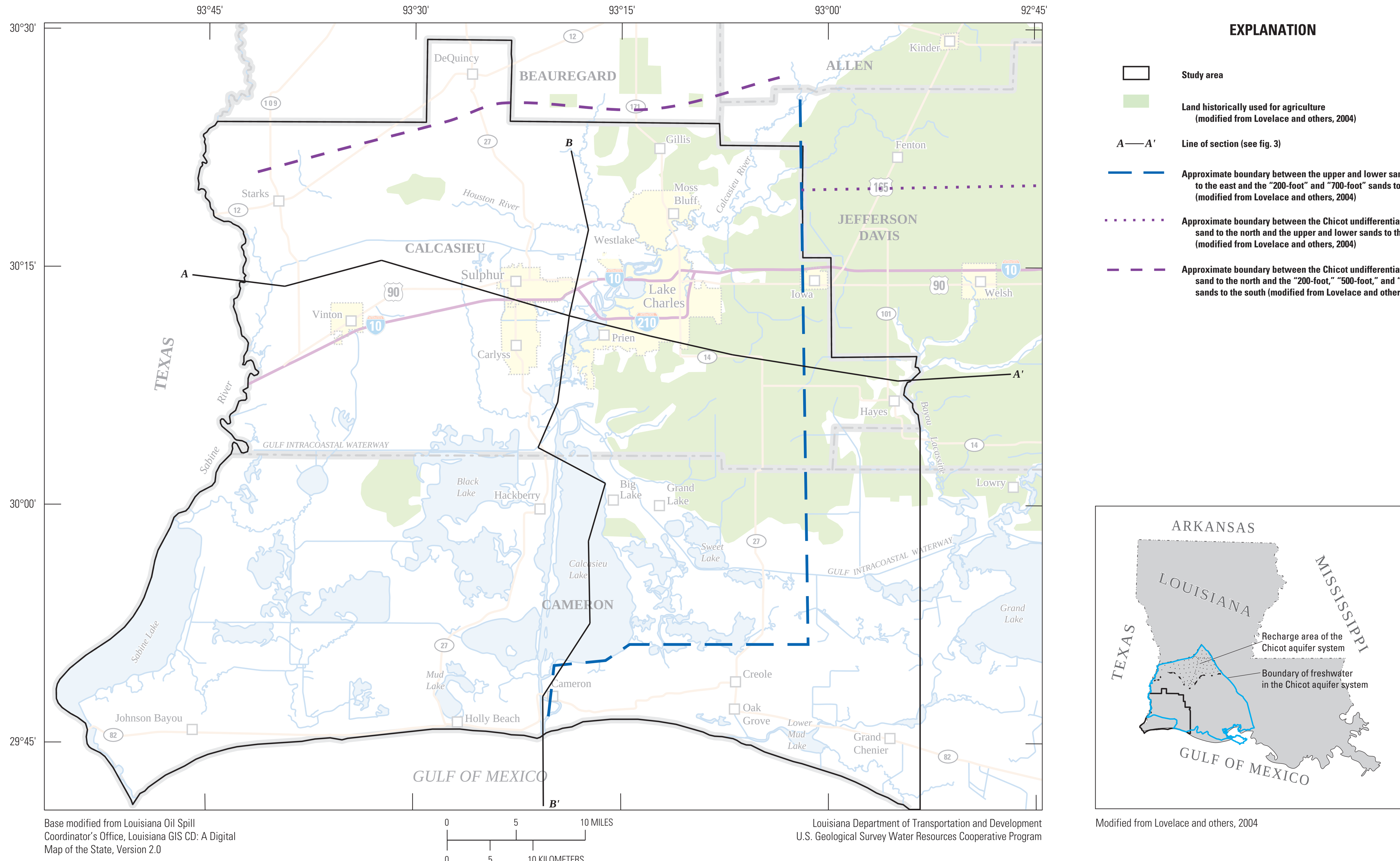

Figure 1. Study area and hydrogeologic cross-section lines. Cross sections shown on figure 3.

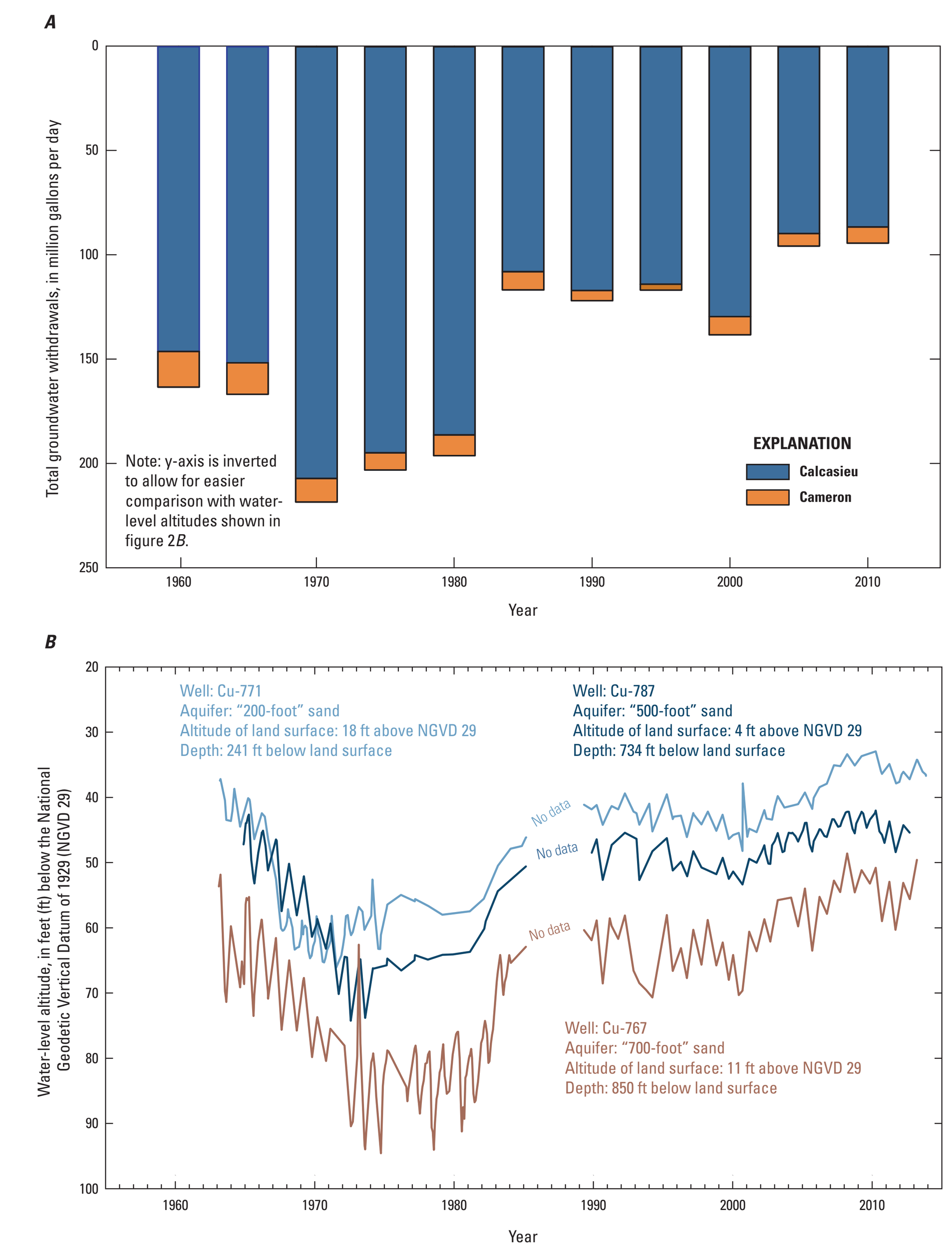

Figure 2. *A*, Total groundwater withdrawals in Calcasieu and Cameron Parishes, southwestern Louisiana, 1960–2010, and *B*, water levels for wells screened in the "200-foot," "500-foot," and "700-foot" sands (well locations are shown in figs. 5, 9, 13). Blank where data are missing.

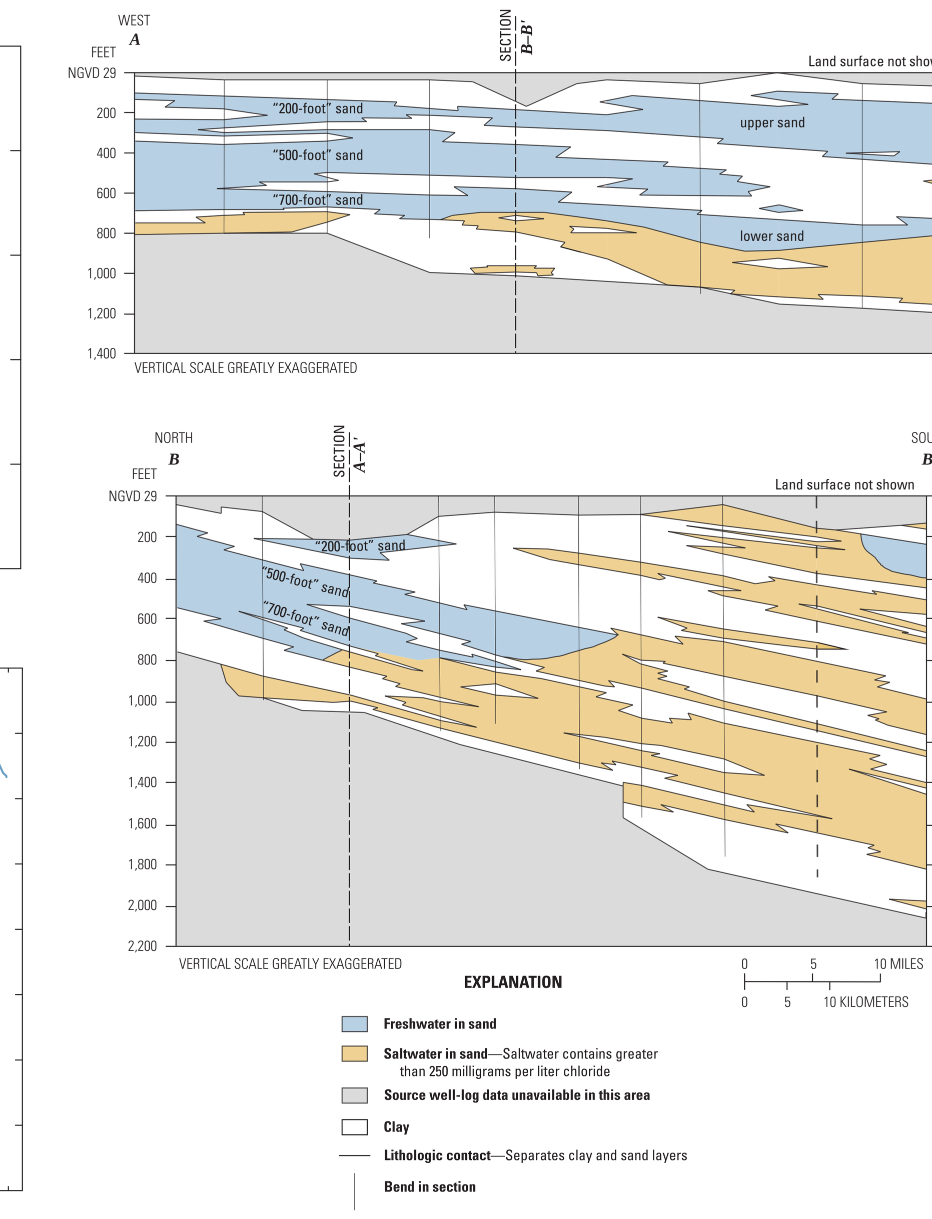

Figure 3. Hydrogeologic cross sections *A*–*A*′ and *B*–*B*′ (see fig. 1 for section trace locations; vertical scale is measured in reference to the National Geodetic Vertical Datum of 1929 (NGVD 29); modified from Nyman, 1984).

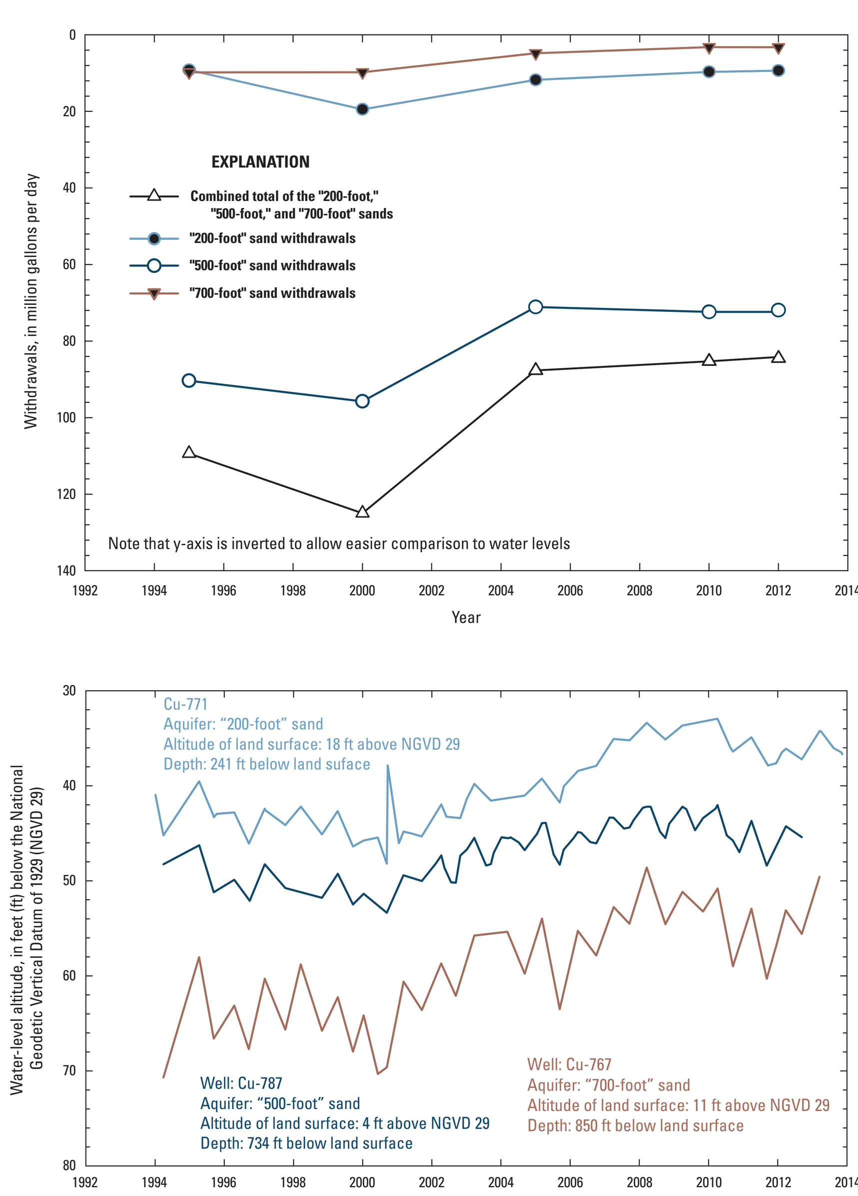

Figure 4. *A*, Groundwater withdrawals and *B*, water levels from wells screened in the "200-foot," "500-foot," and "700-foot" sands of the Lake Charles area in Calcasieu and Cameron Parishes, southwestern Louisiana (water levels are presented in feet below the National Geodetic Vertical Datum of 1929 (NGVD 29); well locations are shown on figs. 5, 9, and 13).

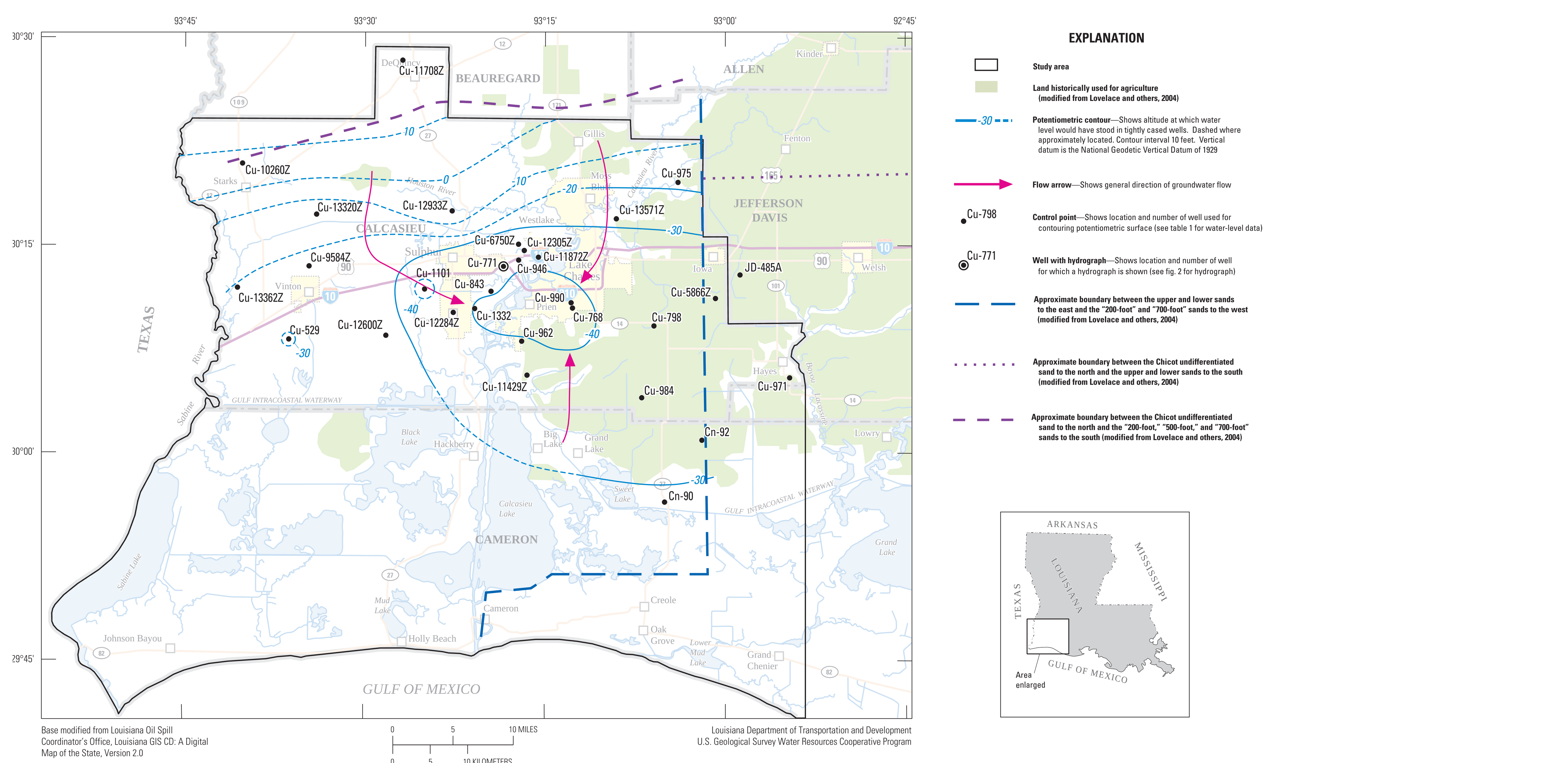

Figure 5. Potentiometric surface of wells screened in the "200-foot" sand of the Lake Charles area and upper and undifferentiated sands of the Chicot aquifer system, southwestern Louisiana, December 2011–March 2012.

Potentiometric Surfaces, 2011–12, and Water-Level Differences Between 1995 and 2011–12, in Wells of the "200-Foot," "500-Foot," and "700-Foot" Sands of the Lake Charles Area, Southwestern Louisiana

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